

SD11
A55
1946

NORTHEASTERN FOREST EXPERIMENT STATION
OFFICE LIBRARY

ANNUAL REPORT

1946

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

REED W. BAILEY
Director



WMB
E/R

United States Department of Agriculture
Forest Service
Ogden, Utah

RESEARCH AND THE FUTURE OF THE INTERMOUNTAIN WEST

Of the resources flowing from our public lands we tend to give precedence in our thinking to those of direct, tangible character. People generally visualize the resources of forest and grazing lands primarily in terms of timber and forage. These resources have played a direct and obvious role in building the West, and when local timber supplies are exhausted or when forage runs out, the consequences are also direct and obvious. The difference between wealth and poverty is clear.

But the less direct and tangible values of our public lands--recreation and watershed--have been slower to receive recognition. It cannot be said that they are adequately recognized even today. Forest recreation has been growing rapidly for years, conditioned largely by social and economic factors that were little in evidence a hundred years ago. And, as these social and economic forces are still in a state of flux, it is impossible to predict with any accuracy what the magnitude of future needs will be. It is safe to say only that future values of forest recreation will be greater than present values.

Watershed values are tangible, but they are rather remote from the ordinary person's understanding. It is a long way from the melting snow crystal of April to the water in tap and teakettle in September. It is a long way from the flood that we read about in the paper today to the denuded slopes of 40 years ago, not yet recovered. It is a long way, in most people's thinking, even to persistent overgrazing during recent years.

Because it is easier to place a value on plant cover in terms of forage or saw timber than in terms of watershed protection or esthetics, we are led unconsciously to reason as if these direct and tangible values were somehow the greater. For example, it is easier to conclude that forage left ungrazed at the end of the summer season is wasted forage than that it is necessary for protection of the soil. We can compute in animal unit months and dollars and cents just what grazing revenue amounts to, but we have no measuring stick, financial or otherwise, by which we can appraise the value of watershed cover. We put watershed value on the scales only when, by obvious signs of accelerated erosion, we can see that the watershed needs protection. When these signs are obvious, the watershed has either had a terrific beating or it has been in unsatisfactory condition over a long period of time--either of which means that our discovery has come too late. Hence, while we are aware of grazing values in a positive sense, we think of watershed values chiefly in a negative sense. The reason why we tend to think only of forage, when signs of accelerated erosion are not obvious, or when they are absent, is that forage is all we can see, and we minimize greater values simply because they are not dramatically placed before our eyes.

But these less obvious and tangible resources are growing more and more in importance--or, rather, we are growing more and more to appreciate their importance. National forest recreation in Region 4 was almost twice in 1946 what it was in 1945--a participant use of 3.1 as compared with 1.8 million visits--and exceeded by about half a million the pre-war record in 1940. Competition for water has always been keen. Litigation has been common, and even violent death not unknown, in otherwise peaceful, law-abiding agricultural communities, over water rights. And industry competes with agriculture for water.

All signs point toward increasingly keen competition in the future. The industrial developments in the West during the last war are not being liquidated. They are being maintained--the Geneva steel plant, for example--and new industries are moving in. The underlying trend is not attributable to the war. In the pre-war decade 1930-1940, according to the Sixteenth Census, population of the western states increased 16.7 percent, as compared with an increase of 7.2 percent for the country as a whole, and the majority of people who moved in as a result of the war boom are staying. The population of Utah has increased from 500,000 to 600,000 since the beginning of hostilities, and the population of Weber County alone--one of several counties whose people are concentrated along the Wasatch Front--increased 29 percent between 1940 and 1946. It is estimated by the Utah State Department of Publicity and Industrial Development that the population of the state will double during the next 20 years.

More industry means a keener competition for an already deficient water supply. To supply the proposed thermoid plant at Nephi, Utah, for example, it has been necessary to buy up water heretofore used for crops. The enormous quantities of water required for processing manufactured products, the amounts held back in reservoirs for power and released during seasons when the water cannot be used again in irrigation, cannot help but tell against a limited supply. But more industry and more people mean a greater demand for local agricultural products, and it is safe to say that the Intermountain region will never become so highly industrialized that agriculture will be no longer important. Vegetables, cereals, dairy products, meat, hides, wool, lumber--our needs for these will be increasingly greater, not less. Forest and range lands will increase in importance for these values alone, over and above their increasing importance for watershed values.

The manager of wildland resources obviously faces mounting problems and pressures. More reservoirs, more industry, more irrigation canals, more population, mean higher values, and they mean that mistakes in wildland management tolerated in the past will be intolerable in the future. A maximum, safe water supply is increasingly essential and so is freedom from man-caused floods. But full, safe use of forage, timber, and recreational resources is also highly necessary.

Some 40 years ago the national forests of the Intermountain region were established, chiefly for watershed protection, and in that 40 years the necessity for watershed protection has intensified. Most of these national forests are not thickly clothed with timber; all contain large areas of

rangeland with very little timber. This rangeland, covered as it may be with grass or brush, is fully as important and valuable from the watershed standpoint as if it were covered with trees.

In fact these range-watershed lands are more important, more critical, than if they were timber covered, because they are more valuable for grazing and are more easily damaged by overgrazing. Timber lands may be just as badly overgrazed as any others, but after the ground cover is destroyed, canopy and annual leaf fall still protect the soil in some measure. The worst eroded lands, areas from which floods originate, are lands formerly protected by herbaceous vegetation that has been destroyed. Herbaceous cover, while intact, is as effective as any cover in protecting the soil, but it is the one type of cover most vulnerable to abuse.

Considering both the peculiarities of our watershed resources and needs for the future, it behooves the wildland manager to intensify his efforts. First of all, he must get his house in order. And from now on he must be increasingly able to put into effect more intensive management practices.

Wildland research has an important part to play. It is not true to say that research is already years ahead of practice, and hence can afford to mark time until practice catches up. The fact is that in many fields practice is struggling along as best it can with inadequate help from research. And in any field facts and principles that increase our understanding are developed slowly, at the expense of much effort.

It is true that great progress has been made, as compared with knowledge of 50 years ago, in gaining an understanding of our forests, rangelands, and watersheds. But in spite of the technical progress that has been made, general understanding lags badly. Even today "authorities" declare that floods bear no appreciable relation to watershed vegetation. And the public upon whom the administration of watershed lands depends for support for a balanced, multiple-use program, has little true conception of the relations between plant cover and stream flow.

Research, clearly, has a big job ahead, not only in discovering facts and developing basic principles from them, but in interpreting and disseminating knowledge so that it can be utilized. Moreover, new emphases are coming to the fore. Wildland managers are having to learn to weigh conflicting uses by new criteria--in itself no small task. The intangible, formerly remote values of esthetic use and positive watershed protection justify fully as important a place in a program for "the greatest good of the greatest number in the long run" as the more easily appreciated values of timber and forage. They must be dealt with accordingly, in research as well as administration.

WATERSHED MANAGEMENT AND PROTECTION

Destructive floods and harmful sedimentation, due mainly to excessive surface run-off and accelerated erosion during high intensity summer storms on deteriorated watershed lands and acute water shortages, due to low ground water discharges during the summer and fall seasons from the same mountainous lands continue to plague the million people who now live in the semiarid valleys of the Intermountain region. Considerable progress toward the solution of these water problems has been made by research in the field of watershed management and protection but many difficult problems remain to be solved. There is need for effective methods of restoring satisfactory watershed conditions on a wide variety of flood and sediment source areas. There is need for determining how and to what extent the many different forest and range sites in the region can be used without impairing their watershed function. There is need, too, for determining how to obtain increased yields of usable stream flow from the mountain lands.

The search for the solution of these problems was continued last year on a broader scale than has been possible for many years. In addition to continuing studies at the Wasatch research center, it was possible to intensify work at the Great Basin research center to the extent of two full-time technicians and to reopen investigations at the Boise research center on a one-man basis.

Efforts during the year were divided about equally between the continuation of climatic and hydrologic records on the Wasatch and Great Basin experimental watersheds, the compilation, analysis, and preparation of accumulated data for publication, and the analysis of research problems. These efforts brought to light many valuable accomplishments of research to date and the specific needs for further study at each of the three research centers.

CONTROL OF SUMMER FLOODS

The greatest progress of watershed research in the region thus far has been made in efforts to control local summer floods. Study of this problem has centered mainly on the experimental watersheds of the Wasatch Branch Station in Davis County, Utah, where, by 1946, it appears a full cycle of research accomplishment is nearing fruition. Here, where mud-rock flows were destroying a useful community, research not only devised effective methods for preventing the recurrence of these floods but also developed new concepts and principles for the analysis of flood problems elsewhere in the region.

Are Floods Normal or Induced?

The first major research contribution to the solution of the Davis County situation was insistence upon arriving at an answer to the question: "Are the floods normal or are they a new phenomenon induced by changed watershed conditions?" An accurate answer to this question obviously is prerequisite to consideration of an upstream approach to flood control.

A New Approach for Determining Flood Causes

A second major research contribution was made through the development of a new method of analyzing flood causes that is not dependent upon climatic or stream flow records. This method is based on the theory that a stream records its own history and that that history can be determined from geologic, ecologic, and pedologic evidence on the slopes, channels, and flood plains of the drainage basin.

The usefulness of this observational approach was demonstrated in the Davis County area. Studies showed that the size of deposits and depth of channelling made by recent floods were far greater than all of the channelling and deposition that had occurred since the recession of Lake Bonneville many thousands of years ago. By following freshly cut channels, it was found that the sources of flood run-off were localized areas totalling less than 10 percent of the basin area on which the plant cover had been destroyed or drastically impaired by overgrazing and fire and on which the soil was riddled with gullies. Absence of run-off and erosion evidence on intermingled areas in less seriously deteriorated condition made implausible any theory that rainfall alone was responsible for the floods and clearly indicated the true causes of storm run-off to be plant cover deterioration and a newly developed and efficient system of drainage gullies.

A New Design for Flood Control

It was deduced from the observable evidence that floods could be prevented in this locality if the infiltration and storage capacities of the flood source areas were restored to their original effectiveness in preventing surface run-off during high intensity storms. Because run-off was negligible on areas having a relatively dense plant cover and ungullied soil, it was assumed that run-off could be prevented by restoring comparable conditions on the depleted and eroded areas. Rain gages and plots equipped with devices to measure run-off and erosion were installed on both bare and densely covered sites to test the validity of this assumption.

A further important contribution of research was the recognition of the difficulties involved in restoring satisfactory watershed conditions on the flood source areas and the development of a program of measures to accomplish that objective. These measures included (1) public acquisition of the watershed lands so as to make possible greater investments in control measures than could be afforded by private owners; (2) elimination of live-stock grazing and intensification of fire control to prevent the spread of unsatisfactory conditions and to provide maximum opportunity for natural recovery; and (3) contour trenching and reseedling of all areas on which there was evidence of such excessive run-off and active erosion as to preclude the possibility of natural recovery. In addition, stream gaging stations were installed on watersheds which had produced floods prior to treatment and on drainage basins which have not flooded in recent geologic times as a basis for evaluating the effectiveness of the watershed measures.

Measures and Concepts Withstand Tests

The watershed improvement measures have been effective in preventing destructive mud-rock floods on three occasions since 1933, when restoration work was started. In 1934, 1936, and 1945 rains occurred that produced mud-rock floods in adjacent untreated watersheds but failed to produce floods in the treated drainage basins. That no floods occurred in the treated basins in 1945 is especially significant when it is considered that a storm on August 19 of that year subjected the experimental watersheds to rainfall intensities that exceeded the previous maximum rate ever recorded in the state of Utah by about 35 percent.

The storms that caused floods from untreated watersheds in 1936 and 1945 produced from 50 to 160 times more run-off from plots on deteriorated sites than from plots with a dense plant cover. There has been no measurable loss of soil from the densely covered plots since they were established in 1934, whereas those with thin plant cover have lost the equivalent of from 83 to 181 cubic feet of soil per acre on four occasions between 1936 and 1946. These plot records substantiate the conclusions which were drawn from observations on the ground at the start of the study that the floods were caused by excessive run-off from localized, deteriorated headwater areas.

Experimental Watersheds Aid Conservation

The experimental watersheds, in addition to providing effective protection from floods to the people who have reestablished homes at the mouths of the treated canyons, are also serving as a powerful aid to wildland conservation. This watershed laboratory has become a mecca for conservation technicians from all over the world. In 1946 it was inspected by 250 members of the Society of American Foresters during the annual meeting of that organization at Salt Lake City. Moreover, groups of citizens have come from distant parts of the region to study the principles and methods which were developed and applied there as a guide for the correction of unsatisfactory watershed conditions in their own localities.

The people living in the Wellsville Mountain area in northern Utah have already acted to place their watershed lands in public ownership and to start watershed improvements. Other groups are considering like action. Thus research at the Wasatch center has not only developed an effective method for preventing summer floods in that area but has also set in motion an active public interest in the need for adequate watershed protection on the mountainous forest and range lands elsewhere in the region.

Unsolved Flood Problems

A complete solution to the summer flood problem in the region, however, has not yet been attained. The treatments in the Davis County area, though evidently effective, need further checking against the force of still more severe storms. There is need, too, for determining the adaptability of the specific designs used in Davis County on areas of different plant cover and soil mantle condition, such as prevail on the very coarse and loose granitic

soils in southwest Idaho, the heavy soils in eastern Utah, and the highly impervious sandstone soils in southern Utah. Beyond this is the still more difficult problem of finding methods to curb the sustained floods caused by melting snow.

WATERSHED PROTECTION REQUIREMENTS

In addition to the need for effective methods of restoring known flood and sediment source areas, there is equally urgent need for determining the specific conditions of plant cover and soil that are required for preventing watershed deterioration under use. All research to date shows that these requirements must be designed to cope with the destructive forces of high intensity summer rainfall surface run-off.

The Potency of Surface Run-off

Surface run-off as the name implies is stream flow that reaches channels quickly by flowing over the watershed surface. Records from the Great Basin and Wasatch experimental watersheds show this type of stream flow contributes generally less than 5 percent of the annual run-off. However, this type of stream flow may reach instantaneous peak discharges in small drainage basins that are two to three hundred times the maximum discharges of ground water. Such discharges not only rip out and transport enormous quantities of channel fill but also erode irreplaceable soil on the watershed slopes, leaving both slopes and channels increasingly susceptible to more violent discharge with succeeding storms.

Major Surface Run-off Factors

Surface run-off occurs under significantly different hydrologic conditions than ground water discharge. The latter is stream flow which reaches channels by percolating through the soil and rock mantle and occurs only after the mantle receives more water than it can hold against the force of gravity. Surface run-off, on the other hand, occurs whenever rain falls or snow melts at a rate that is faster than it can get into the ground. Precipitation intensity and the infiltration capacity of the soil mantle, therefore, are the major factors that must be considered in designing requirements for the control of surface run-off.

Precipitation Intensity

The maximum rates of rainfall and of snow melt to be expected on the mountainous watershed lands are not yet known with certainty. Rainfall rates up to 6.84 inches per hour for 5-minute periods were recorded on the Wasatch experimental watersheds in 1945. Meteorologists believe even greater intensities are possible.

High intensity summer rainfall is a common phenomenon on the watershed lands of this region, though the recurrence interval of unusually hard storms is not very well known. However, because the occurrence of high intensity storms is both inevitable and unpredictable, it is important that watershed protection be designed to cope with the greatest probable intensities. Any lower standard is bound to result sooner or later in an unprecedented flood and in soil losses that can be replaced only in many centuries.

Infiltration Capacity

The inevitability of high intensity rainfall makes infiltration capacity, or the rate at which water gets into the ground, the focal point of designing for watershed protection. Numerous infiltrometer studies have shown (1) that the infiltration capacity of a given site tends to decrease when wet and eventually to reach a constant rate; (2) that both the initial and the final constant rates differ between sites because of inherent differences in the structure and texture of the soil profile; and (3) that the normal infiltration capacity of a site may be materially reduced by decreasing the density of the plant cover and litter mantle. Soil disturbance, such as is caused by livestock trampling, season of year, and degree of slope are believed to have a bearing on infiltration capacity also, but further study is needed to evaluate the quantitative effects of these factors.

Foresters and conservationists generally have recognized the need for "adequate" plant cover and litter for watershed protection purposes and have made many attempts to describe criteria for that purpose, based principally upon the kind, amount, size, age, and vigor or quality of the plant cover. It is evident from the scope and degree of watershed deterioration in this region that such criteria have been woefully inadequate. Among the reasons for these inadequacies no doubt is the lack of consideration given to the run-off and erosion potentials of the watershed lands under the impact of high intensity rainfall.

Infiltrometers Speed Search for Protection Requirements

This station developed a portable artificial rainmaker in the early 30's to speed up the gathering of run-off and erosion data as a basis for determining the specific conditions of plant cover that are needed for watershed protection. Many of the features of this instrument have been incorporated in the Department's Type F infiltrometer and in the procedures for determining a standard infiltration capacity. The latter procedures involve the application of a constant high rate of simulated rainfall for periods of from 1 to 3 or more hours. These prolonged applications of water are by no means comparable to the average intensity-duration pattern of summer rainfall in this region. Moreover, such applications so alter the run-off characteristics of the plots as to make the measurements of run-off and erosion largely unusable.

To overcome these difficulties, modifications were made in the Type F infiltrometer applicator so as to make it possible to apply rainfall at variable rates comparable to the normal summer rainfall, as well as constant rates. The modified infiltrometers were used in 1945 to measure run-off and erosion caused by a simulated summer storm of 2.44 inches on what were judged to be good, fair, and poor phases of the herbaceous cover-limestone soil complex in the vicinity of the A and B watersheds at the Great Basin Branch Station. The average run-off and erosion rates from the three phases of this complex are as follows:

<u>Site Class</u>	<u>Total plant and litter density</u> (percent)	<u>Run-off</u> (percent)	<u>Erosion</u> (Tons/A./hour)
Good	60-75	2	.05
Fair	30-35	14	.50
Poor	9-10	73	5.50

The very high run-off percent and erosion rate on the sparsely covered "poor" sites are indicative of the tremendous flood and sediment potentials of these watershed lands when they become drastically impaired. That the "fair" sites, with about one-third of the ground surface covered by plants and litter, produced seven times more run-off and ten times more soil loss than the "good" sites clearly indicates that watershed protection in this particular plant-soil complex requires that at least two-thirds of the ground be covered with vegetation and litter.

Many More Tests Needed

Further study is needed in this plant-soil complex to ascertain whether a two-thirds covering of vegetation and litter will maintain its effectiveness in controlling run-off and erosion under grazing use. There is need also for isolating and evaluating the effect of slope and of season on run-off and erosion from this complex as additional useful criteria of watershed protection requirements. Similar specific information is needed for all of the numerous other plant-soil complexes in the region.

WATER SUPPLY PROBLEMS

The plight of Nephi, a small city in central Utah, is typical of the water shortage problems in many localities of the region and of the need for effective measures to increase the usable supply of stream flow from watershed lands. A new industry desires to establish a factory in Nephi. However, stream flow is so limited during the summer and fall months in that locality that the people there are faced with the necessity of condemning a portion of their irrigation water supply in order to make available enough of this essential resource for the new industry. Nephi is but one of many communities in the region which have reached a ceiling of development because of low summer and fall stream flow.

Plans have been suggested to meet the short water supply problem through more efficient conveyance and use of already developed waters and through major reservoir and transmountain diversion projects to make beneficial use of local surpluses of stream flow. These are extremely costly. They do not benefit all areas in short supply nor do they produce any new water. Moreover, they do not stop destructive run-off and erosion at its source but, rather, add to the urgency of effective watershed protection on the mountain slopes above the developed projects.

Increased Water Yields from Watershed Protection

Effective watershed protection must always be the first requirement for managing the mountain lands of this region. This objective, as previously explained, requires the prevention of surface run-off and the stabilization of the soil. In the Davis County area where this objective appears to have been met, the effects of watershed restoration on ground water discharge have been less striking, though distinctly beneficial. Run-off records show that instead of violent discharges of destructive surface run-off, stream flow during summer storms is now entirely usable. This net increase of usable stream flow, though amounting to only a few percent of the annual total, is extremely valuable because it accrues at a time when there is greatest demand for water.

Can Usable Ground Water Yields be Further Increased?

Ninety-five percent or more of the annual run-off from most mountainous drainage basins in this region occurs as ground water discharge. This is fundamentally a process of percolation that is controlled mainly by the volume and timeliness of precipitation, the water-holding capacity of the soil and rock mantle and the amount of water lost through evaporation and transpiration. According to these requirements, ground water yields may be increased to the extent that mantle storage and evapo-transpiration losses can be reduced and to the extent that additional quantities of precipitation can be made to enter the soil and rock mantle. Studies here and elsewhere have demonstrated the feasibility of materially affecting all three of these controlling factors through manipulation of the plant cover but application of such measures in this region must be approached with caution and in such a manner as not to increase the already high hazard of destructive run-off.

Mantle Retention--Storage Must be Sustained

Studies of precipitation, soil moisture, and stream flow records at the Wasatch and Great Basin research centers show that the watershed mantle must receive from two to three inches of precipitation per foot of soil depth before it will yield gravitational water for seepage flow. Any loss of soil is bound to reduce both the detention--and retention--capacity of the watershed mantle and thus to increase the magnitude of stream flow peak discharges. A change in stream flow characteristics in this direction through a lessening of the storage capacity of the soil mantle is clearly inimical to both flood protection and the yield of prolonged usable stream flow. If there is need for changing the storage capacity of the soil mantle in this region it is in the direction of restoring and increasing it, even though such a change may mean some reduction in the annual total run-off.

Promising Measures for Increasing Usable Stream Flow

A number of watershed management measures offer promise of increasing or prolonging ground water yields in this region. Tests at the Wasatch research center show that surplus spring run-off can be spread in dense oakbrush for underground storage at rates up to 3-acre feet per acre of spreading area per day without causing erosion. This suggests that similar spreading on upstream areas may be effective in lowering spring peak discharges and in delaying the recession of summer stream flow. Recent studies show that one-third of the late summer stream flow in Farmington Creek is dissipated by evaporation and transpiration. Further study is needed to determine the feasibility of decreasing these losses by suppression of stream bank vegetation and by conveyance of stream flow in pipes. Artificial reseeding studies have developed increasingly effective methods of establishing highly productive stands of palatable grass in aspen, mountain brush, and sagebrush areas. If experiments show that interception and evapo-transpiration losses are reduced by converting aspen and brush areas to grass without impairment of soil stability, the extension of such measures to the several millions of acres of mountain lands which are susceptible to treatment offers great promise of both increased range forage and useful ground water yields.

RESEARCH CENTER WATERSHED PROBLEMS AND PROGRAMS

Essentially similar problems of watershed protection, restoration, and water yield management exist within the provinces of the Great Basin, Wasatch, and Boise research centers. However, the criticality of these problems and the specific needs for research toward their solution differ because of differences in drainage basin characteristics and economic development.

Great Basin Research Center

The Great Basin research center work province includes all but the western desert portion of the Sevier Lake drainage basin, a rectangular shaped area of about 7,500 square miles in southwestern Utah. This province is dominated by extensive partially dissected plateaus and mountains, the crests of which are at from 9,000 to 12,000 feet elevation and by relatively restricted block-fault valleys that lie at elevations of about 5,000 to 6,000 feet.

The Sevier River is the major stream in the province. It rises in the south, flows north, then westward to drain into Sevier Lake. The main river is fed by numerous short, high gradient streams which rise on steep headwater lands, follow high gradient channels in narrow canyons and enter the main valleys on alluvial fans. The channels of many of the streams are badly ripped and actively eroding.

Average annual precipitation ranges from about 10 inches in the valleys to about 30 inches along the crest of the mountains and plateaus. Precipitation occurs mostly as snow during the winter months, particularly at the higher elevations where it may accumulate up to depths of 10 feet. Summer precipitation occurs most commonly as high intensity rainfall of short duration.

Valley soils are mostly alluvial, deep and productive on the drained slopes near the mountains but many are alkaline and unfit for cropping on extreme bottom lands. Mountain and foothill soils are mostly residual but vary widely with respect to their infiltration capacity and stability. The soil on about 56 percent of the mountain and foothill portion of the province is derived from igneous and metamorphic parent material. These soils have relatively high infiltration capacities and are the most stable. Soils derived from sandstone tend to be relatively impervious and are highly susceptible to erosion. The surface horizons of soils derived from limestone are favorable to infiltration but frequently have substrata of less pervious material which inhibits deep percolation of water. Accelerated erosion is widespread and is especially active on localized headwater slopes.

Open stands of pinyon-juniper occupy 37 percent of the province, mostly on the valley and foothill lands at the lower elevations. Sagebrush is also common at the lower elevations and occupies 27 percent of the area. Mountain brush occupies 18 percent of the area, mostly at intermediate elevations on the mountain slopes. Stands of aspen, conifers and subalpine grasses occupy 8 percent, 6 percent, and 4 percent of the area, respectively, all at the higher elevations. The species and density of the plant cover within each of these major categories varies widely from spot to spot by reason of local differences in aspect, slope, and soil. Overgrazing by livestock and big game has caused a material reduction in the density of herbaceous and shrubby vegetation in all of the cover types. Serious soil losses are occurring on 58 percent of the subalpine grassland areas, on 47 percent of the pinyon-juniper areas, and on 32 percent of the sagebrush areas.

Eighty percent of the land in the province is publicly owned, including 3,539 square miles in national forests, 2,069 in grazing districts, 55 in other federal, and 381 in state. Privately owned lands include about 80 square miles of dry farm, 220 square miles of irrigated farm and pasture, and 1,160 square miles of range land.

Occupancy centers in numerous small towns and villages, practically all of which are situated on fans at or near the mouth of a mountainous tributary drainage basin. The economy is dominated by mostly very small, combination farm-livestock enterprises. These enterprises are based in part upon irrigated crop production on about 400,000 acres of valley lands. They are also dependent on local watershed lands for a considerable part of the year-long forage supply, for farm timbers, posts and fuel, and for water for domestic, irrigation, power, and industrial uses. Livestock and some crops are exported but many of the farm and forest products are used locally.

Watershed Research Problems

Destructive debris-laden summer floods have become a common occurrence throughout the basin, due in large measure to deterioration of the plant cover and soil mantle on watershed slopes as a result of overgrazing by range livestock and big game and, to a lesser extent, fire. A recent Department flood control survey reveals that flood and sedimentation damages average \$600,000 annually and that damages will increase unless remedial measures are installed.

Irrigation agriculture, industry and communities have long since reached a ceiling of development in most parts of the province because of a limited water supply. Water is short not only because of low annual yields of stream flow from the watershed land but also because 60 percent of the annual run-off occurs in the spring when it cannot be used efficiently and because stream flow in the late summer dwindles to a mere trickle. Reservoirs on the main Sevier River rarely fill and these projects do not help the water users with prior water rights who get their supply by direct diversion from the tributary mountain streams where surface storage structures are largely infeasible.

The flood and water shortage situations pose three major problems in watershed research including (1) determination of watershed protection requirements for the large number of different plant-soil complexes in the province to prevent further watershed deterioration under use; (2) development of suitable measures for restoring effective conditions for water flow retardation and soil erosion on the many different flood source areas which have already developed; and (3) development of plant cover treatments that will reduce evapo-transpiration losses and retard snow melting and thus increase the yield of usable stream flow.

Studies of watershed protection requirements must isolate and evaluate the factors of aspect, slope and season in addition to plant cover density and soil disturbance under the impact of high intensity rainfall, and develop criteria for recognizing the minimum requirements for protection. The large number of factors, the extensive area involved and the unpredictable occurrence of effective rainfall precludes approaching this problem by means of full-scale experimental watersheds. In lieu of this approach, it is proposed to initiate a long-range program of infiltrometer studies in all of the major plant cover-soil complexes, supplemented by a restricted number of permanent erosion plots and the continuation of the A-B watershed study through its present phase of determining the effect of heavy grazing on area B.

Studies of watershed restoration will necessarily involve the development or adaptation and testing of both artificial revegetation methods and mechanical control structures for a wide variety of soil conditions, mainly within the herbaceous grassland types. It is proposed to concentrate studies on limestone soil areas at first because methods which prove to be effective in coping with the impervious substratum that is commonly characteristic of such sites, theoretically, should be adaptable to other soil conditions in the province.

Studies of water yield management require separate consideration of evapo-transpiration losses, of snow accumulation and melting, and of upstream water spreading. It is proposed to initiate studies: (1) of evapo-transpiration losses in the mountain brush and aspen zones because of their extensive occurrence in water yielding altitudes and their susceptibility of conversion to grass by artificial reseeding; (2) of snow accumulation and retardation of melting in the subalpine grassland and fir zones because of the maximum depths of snow and the most feasible means of inducing drifting at those altitudes; and (3) of spring season water spreading on the plateau benchlands mostly at high elevations.

1947 Studies Program

1. Continue the A-B watershed study. This to involve (a) continuation of heavy grazing on area B to reduce plant cover density to 20 percent or less; (b) maintain current run-off, erosion, and climatic records; and (c) install flumes and waterstage recorders at intake of area A and B run-off and sediment collecting tanks.
2. Continue infiltrometer study of watershed protection requirements within herbaceous cover-limestone soil complex. This will involve use of a two-man Type F infiltrometer to isolate effects of such variables as (a) 25-, 35-, and 45-percent plant cover densities, (b) seasonal effects of June, July, August, and September, (c) trampling and clipping, and (d) design rainfall applications on dry and wet ground and (e) constant rainfall on wet ground.
3. Initiate a study of watershed restoration methods on flood source areas in the herbaceous cover-limestone soil complex. This study will include immediate exploratory trials of control measures and subsequent application of the best measures on the 10-acre A-B watersheds which are equipped to measure effects of treatment on surface run-off and erosion and on the larger Lefthand Fork and Alpine cattle pasture watersheds which are equipped to measure ground water run-off. Work this year will include completion of rating curves for all flumes, conversion of gage height records to discharge, and the preparation of run-off and climatic records of analysis.
4. Explore suitable areas for initiating studies of evapo-transpiration losses, snow accumulation and melting, and upstream water spreading.

The Boise Research Center

The Boise research province, comprising an area of 25 million acres in southwestern Idaho, extends from the vicinity of American Falls on Snake River on the east westward to the Oregon border, and from the Utah border on the south northward to embrace the Salmon River drainage.

Physiographically, the province is divided into the sparsely settled, interspersed lava plains and mountains southwest of the Snake River valley, valuable chiefly for grazing; the heavily populated Snake River and tributary valleys, mainly valuable for the 1.3 million acres devoted to irrigation agriculture; and the lightly populated mountainous area north of the Snake River valley, valuable chiefly in that it furnishes over 65 percent of the water resource for irrigation outside the Snake River valley as well as forage for summer grazing of livestock, commercial timber, and some gold.

The climate of this province is of the Pacific coastal type, being characterized by wet winters, during which deep snow accumulates in the mountains, to depths of from 3 to 10 feet, and by dry, almost rainless summers, during which frequent "dry" lightning storms and occasional high intensity localized rains occur, especially in the mountains.

The mountainous area north of the Snake River is characterized by many deep V-shaped canyons and sharp ridges with very steep slopes. On seventy-two percent of the area slopes have gradients of 45 percent or greater. Soils are predominantly residual, mostly derived from granitic and rhyolite parent material. They are loose grained, coarse textured, friable, and non-cohesive. Those on steeper slopes tend to be shallower, coarser in texture, less fertile, and more erodible than those found on gentle slopes and bottom lands. Infiltration studies show that these granitic soils in normal condition have an average infiltration capacity of from 4 to 7 inches per hour. On areas where the cover is depleted, however, the infiltration capacity may be less than 3 inches per hour and as low as one-fourth of an inch per hour.

Upper slopes are forested with lodgepole pine, spruce, Douglas fir, and ponderosa pine, much of the latter cut over and burned. Lower slopes are brush and grass covered with widespread encroachment of inflammable cheat-grass. There is extensive serious erosion, especially in the range and burned forest cover types.

The province is 85 percent publicly owned. About 9 million acres, including nearly all of the mountainous portion, are in national forests. Some 10 million acres, mostly foothill lands, are in grazing districts. There are about 2.5 million acres of privately owned uncultivated lands, mostly in the foothills. About 1.3 million acres are privately owned cultivated valley lands.

Irrigation agriculture on some 760,000 acres of land in the main Snake River valley and on an additional 540,000 acres in the valleys of the major tributary rivers, notably the Boise, Payette, Weiser, and Bruneau, is the dominant enterprise in the province. This enterprise has been made possible by the construction of large reservoirs on the main streams and of extensive systems of irrigation canals and laterals.

Supplementing the intensive agriculture on the irrigated lands is a large and important range livestock industry which is dependent upon the mountainous land for summer forage, and upon the foothill and valley lands for fall, winter, and spring forage. Logging and lumbering operations are becoming increasingly active through the opening of formerly inaccessible timber stands. Placer mining for gold, once very active in the Boise River drainage, is continuing on a small scale and new stibnite mines have been developed recently in the Salmon River drainage basin. Food processing factories are increasing. There has been little change in rural population in recent years but war activities have materially increased the number of people in such cities as Boise, Nampa, Twin Falls, and Weiser.

Watershed Research Problems

Abatement of damaging sedimentation in irrigation facilities and control of destructive local summer floods are the most serious watershed problems in this province at the present time. These are most critical on the mountainous granitic soil areas in the Boise and Payette River drainage basins. Here, there is widespread accelerated erosion on seriously depleted areas in the

grass, brush-grass, and ponderosa pine types due mainly to overgrazing by range livestock but also to fire and logging disturbance. Soils are displaced mainly by excessive surface run-off during localized high intensity summer rains. Eroded soil and debris are carried into larger tributaries where they lodge temporarily, to be swept downstream by the sustained high run-off during the spring snow melt into reservoirs, canals, and farm ditches, and into the main river channels. Average annual damages from flood-borne sediments in the irrigation facilities of Boise valley alone total some \$300,000. Here, also, deposition of sediments in the main river channel through Boise valley by decreasing its capacity to pass stream flow is increasing the frequency and magnitude of spring flood damages. The city of Boise has also been damaged directly by summer floods from local tributaries.

Spring floods from rapid melting of snow and shortages of irrigation water due to low base flow in the summer months have become increasingly serious in the Boise, Payette, and Weiser valleys. Multiple purpose reservoir and trans-basin storage and diversion projects now under construction or planned for these and the main Snake River basins, will minimize the spring flood hazard, provide supplemental irrigation water for many units that are now deficient and full supplies for about another 900,000 acres. These plans represent the ultimate in water conservation by means of channel improvements and will establish a ceiling of agricultural development. Because they will not actually develop any new supplies of water, they do not preclude the desirability of seeking increased yields of usable stream flow and lowered spring flood peaks through treatment of the watershed cover. Moreover, the projected construction projects are extremely costly and their installation will greatly augment the already urgent need for effective control of erosion on the watershed slopes.

The watershed protection problem is of immediate concern, especially in the Boise and Payette drainage basins. Continued accelerated erosion under considerably reduced grazing pressure clearly shows there is need for more reliable criteria of satisfactory watershed protection requirements and of more effective measures for restoring favorable conditions on steep slopes with shallow, eroded soil and impaired plant cover. In the reactivation of field work in the Boise area it is proposed to devote the great bulk of initial efforts to these two phases of watershed protection with only minor and supplementary studies on water yield.

1947 Studies Program

1. Initiate an infiltrometer study of watershed protection requirements in the grass cover-granitic soil complex. This will involve (a) completion of development, construction, and calibration of a light-weight, 2-man infiltrometer; (b) exploratory test runs to determine the number of plots and replications necessary for experiments to evaluate the factors of slope, seasonal use, soil disturbance, and plant cover density; and (c) selection of sites for detailed tests and for supplemental permanent erosion plots.

2. Reactivate watershed restoration study on three subbasins in Woodtick drainage. This will involve improvement of old water control sections, construction of debris basins and the reinstallation and operation of waterstage recorders and climatological instruments on each of the three subbasins.
3. Make exploratory study of sites and methods for initiating evapo-transpiration and snow accumulation and melting studies within the ponderosa pine and spruce-fir types.

Wasatch Research Center

This province embraces 11 million acres of land draining into Great Salt Lake, exclusive of salt desert shrub areas, in northern Utah. The east portion is dominated by high mountains and relatively narrow valleys which are drained by the Bear, Logan, Ogden, Weber, Jordan, Provo, and Spanish Fork Rivers. The mountainous portion ends abruptly along a very steep western front which extends along a generally north-south axis for a distance of about 150 miles through the center of the province. This front is drained by numerous short, high gradient streams. Gently sloping old lake terraces, fans and deltas, and bottom lands extend westward from the base of the mountain front to Great Salt Lake.

Annual precipitation averages 10 to 15 inches in the valleys and 30 to 50 inches in the mountains, most of which occurs as snow in winter. Local, high intensity rainfall is common in the summer.

Mountain soils are highly variable in depth and texture, largely by reason of differences in the nature of the parent rock material from which they are derived. Extremes include fairly deep, gravelly loam soils derived from old granite, gneiss, and schists as found on the Wasatch Front in Davis County and shallow, heavy clay soils that have developed from sedimentary formations in the Weber River basin. Accelerated erosion is occurring both locally and extensively.

Spruce, fir, lodgepole pine, and aspen occur in patches on the mountains, generally at elevations above 7,500 feet. Mountain brush is common on the lower mountain slopes. Foothills and valleys are largely occupied by extensive stands of sagebrush interspersed with less extensive stands of juniper. The herbaceous understory is considerably depleted on the mountain lands and drastically depleted on foothill and valley lands.

About 70 percent of the province is publicly owned, including 2.2 million acres in national forests, 2.9 million acres in grazing districts, 2.8 million acres in other federal status including about 1.8 million acres of desert waste, and about 600,000 acres in state ownership. In private ownership are about 2.5 million acres of range land and 900,000 acres of cropland, of which nearly 500,000 is irrigated.

The mountain lands of the province are the source of vital water supplies for 65 percent of all the people, 60 percent of all cropland, practically all manufacturing and processing enterprises, and most of the hydro-electric power generated in the state of Utah. These lands are also used intensively for livestock grazing and for all forms of outdoor recreation. The forested portion provides about one-fifth of the local lumber requirements, practically all of the local requirements for farm timbers, posts and poles, and a large volume of ties and mine props for both local use and export. The valley and foothill lands are used very intensively for spring and fall grazing of livestock.

The economy of the province is on the threshold of a change from one based largely on agriculture and mining to one that will also include a major element of manufacturing and fabrication. This opportunity has come about through the construction of the large Geneva steel plant near Provo which will provide materials for a wide variety of supplementary and complementary enterprises. Industrial expansion has already started in Ogden, Salt Lake City, Provo, and Nephi, and more new enterprises are planned for the immediate future.

Watershed Research Problems

Destructive local floods and damaging sedimentation in irrigation facilities have long been of serious concern in this province, especially along the steep front of the Wasatch mountains. Plant cover deterioration and reduced infiltration capacity on localized headwater areas induced by overgrazing and fire are known to be important contributing factors in most cases and in many cases the major factor, toward their occurrence.

Concern is also deepening over the absence of additional, readily available water supplies to meet present requirements of irrigation, industrial, and domestic uses. Water shortages stem in part from meager annual run-off but more particularly to very low stream flow in the summer months and the lack of feasible surface storage sites in many of the steep tributaries.

The solution of the flood and sedimentation problem requires further research on both watershed restoration methods and watershed protection requirements. Watershed restoration studies are needed to further evaluate the effects of contour trenching on the deep and loamy soils of the Wasatch mountains in Davis County and to develop standards for similar treatments on the shallow and heavy clay soils that are common in the Weber River drainage basin. Watershed protection requirement studies are needed on the several plant cover-soil complexes characteristic of the steep Wasatch Front and on the still more numerous plant cover-soil complexes of the more extensive mountainous headwaters of the Bear, Ogden, Weber, Jordan, Provo, and Spanish Fork Rivers.

It is proposed to prosecute the watershed restoration program through studies of methods and standards and to limit evaluation of effects to a few watersheds. The watershed protection program will require extensive study by means of infiltrometers in order to evaluate the numerous factors and criteria in the shortest possible time, supplemented by permanent erosion

plots and a few grazing tests on full scale watersheds. It is proposed to limit the watershed protection studies for the time being to three pairs of subbasins of Farmington Canyon.

Solution of the water supply problem lies in watershed treatments which will reduce evapo-transpiration losses on drained slopes and along streams, increase snow accumulation, and retard snow melting, and increase detention storage during spring run-off. It is proposed to confine evapo-transpiration studies on drained slopes to the aspen and mountain brush zones because these areas are most susceptible to conversion to grass by artificial reseeding; and along streams to reaches of moderate gradient. Snow studies will be confined to the aspen and conifer stands at high elevations where there are maximum snow depths. Water spreading studies also will be confined to the higher elevations where it is believed maximum delay and reduction of spring peak discharge can be achieved.

1947 Studies Program

1. Continue evaluation of contour trench method of watershed restoration at the Wasatch Branch. This will involve (a) maintenance of stream flow and climatic records on Parrish (treated) and Centerville (untreated) watersheds and on Halfway (treated) and Morris (untreated) subbasins of Farmington drainage; and (b) preparation of discharge and climatic records for analysis.
2. Continue Parrish Creek plot study of watershed protection requirements. This will involve treatment of the plots to establish various conditions of plant cover and litter density and the maintenance of run-off, erosion, and related climatological records.
3. Continue watershed study of protection requirements. This will involve (a) maintenance of stream flow and climatic records on Miller and Whipple subbasins scheduled for no grazing, on Hellingworth and Rice substations scheduled for moderate grazing, and on Bigler and Hellhole subbasins scheduled for light grazing; and (b) preparation of discharge and climatological records for analysis.
4. Continue soil pit study of evapo-transpiration loss in aspen and brush type. This involves maintenance of soil moisture and climatic records and, if available, test of Coleman soil moisture meter.
5. Continue study of riparian water loss. This involves maintenance of stream flow and climatic records on Mud and Van Fleet subbasins, preparation of discharge records for analysis and exploratory studies of methods of treating riparian vegetation.
6. Explore possibilities for initiating studies of upstream water spreading in Farmington Canyon and of watershed restoration and protection studies in the Weber River drainage basin.

Publication Schedule for 1947

Site class flood potentials	Jour. For.	Lull
Evapo-transpiration losses from streams	West. Snow Conf.	Croft
Davis County watershed study	USDA Circular	Bailey, Croft, & Craddock
High intensity summer rainfall	Weather Bureau	Marston
Observations on snow melting rates	AGU	Croft, Marston
Variable infiltrometer rainfall	AGU	Johnson
Some erosion criteria	Jour. For.	Lull
A new infiltrometer	AGU	Packer

GRAZING MANAGEMENT

Summer Range

Summer range occupies only a little more than one-fifth of the total area of range land in the Intermountain region, some 31 out of 146 million acres. Its strategic importance is much greater than this proportion would suggest, however. First, summer range forms a vital link in the yearlong livestock operation, furnishing the forage on which annual weight gains and growth of young animals are made. Second, summer range is primarily mountain range, where conflicts with other land values--particularly watershed values--are most serious.

Because of their great areal extent there is wide latitude for variation in winter range and spring-fall range in the Intermountain region; but in the case of summer--mountain--range, variation is enormously greater. Superimposed upon variations in climate, soil, and vegetation to be expected within an areal extent of some 10 degrees of latitude and 11 degrees of longitude, are variations in mountain range accompanying altitudinal changes in a single locality up to a mile and a half, variations with exposure to any point of the compass, and variations with slope steepnesses from zero up to 100 percent.

The problems of mountain range, the chief of which will be outlined briefly here, are of a kind to challenge the land manager's utmost efforts, both from the standpoints of the difficulty of their solution, and of the values involved. Inasmuch as most mountain range in this region is under national forest administration, management research on mountain range is of particular interest to the Forest Service because it ties in directly with the Service's determination "to get on top of" its range problem.

Broadly, the problem in administering mountain range is to balance stocking with grazing capacity, at the same time reconciling grazing with other wildland uses. The specific problem on a given area requires that the land manager understand the effects of animals, domestic and wild, on that kind of range, that he be able to evaluate the condition of that range in relation to its potential, and that he be able to judge whether or not current management measures are bringing about the changes he desires. The job of summer range management research is to discover facts and principles to answer specific questions in these fields.

The research attack is outlined briefly here under four heads. These have to do, first, with developing standards for judging range condition and trend, secondly with increasing plant cover, thirdly with understanding the relation of animals other than livestock to the range, and fourthly with formulating a comprehensive problem analysis for research on these important range-watershed lands.

Develop Standards for Judging Range Condition and Trend

The first work on range condition and trend in the Intermountain region was Sampson's study on succession in the subalpine zone of the Wasatch Plateau, published in 1919. In 1939 Clark and Hansen prepared a mimeographed utilization handbook for the Intermountain region. In 1944 Ellison and Croft prepared Research Paper No. 6 on judging condition and trend of high range-watersheds.

Range condition and the Mt. Pleasant flood: Damage caused by the Mt. Pleasant flood of July 24 is treated elsewhere in this report. The relation between this flood and condition of the watershed will be considered briefly here.

The cause of the flood was the occurrence of a local storm of great intensity upon steep slopes inadequately clothed with vegetation. According to an investigation made by our Flood Control Survey, nearly all the flood run-off came from less than 1,300 acres of depleted herbaceous cover near the crest of the Plateau--in other words, from only about 10 percent of the entire Mt. Pleasant watershed.

There was ample evidence on the ground afterwards to indicate how water had poured over the soil surface. This evidence consisted of rills, pedestalled plants, fresh-cut gullies, exposed roots of plants, plants lying downslope in parallel ranks, some of them partly buried by small deposits of sediment, accumulations of fresh sediment in natural catchment basins, and alluvial deposits of gravel in clumps of vegetation or where slopes abruptly lessen.

It is important to understand that these indicators of accelerated erosion were to be found not only after the storm of July 24, but also before it. Some of them--gullies, pedestalled plants, abnormal exposures of bared soil--have been plainly visible at any time over many years to anyone walking or riding over the watershed. Others, like fresh cutting or signs of recent surface washing, have been most plainly visible shortly after storms. Undoubtedly these signs of accelerated erosion have been more or less continuously in evidence since the similar Mt. Pleasant flood of 1918. And they were undoubtedly very much in evidence for some 30 years before that.

The Mt. Pleasant flood emphasizes dramatically that indicators of accelerated erosion are danger signals. They point to a persisting hazard. If they are ignored or disregarded, the results may be catastrophic. Indicators of current accelerated erosion elsewhere on the Wasatch Plateau are also danger signals. With localized storms of similarly high intensity, similar floods will follow elsewhere. And the results may well be more catastrophic than those at Mt. Pleasant, for many other towns are located at the very mouths of the canyons, not three miles away on a gently sloping alluvial fan, as Mt. Pleasant is.

While it is important to relate the Mt. Pleasant flood to the warning indicators on the watershed, it must be realized that these indicators mean more than flood danger. They point to a widespread destruction of substance which we are not, for all our efforts at conservation, doing very much about. The same small storm that produced the Mt. Pleasant flood, for example, caused flooding in several drainages east of the divide. These did some damage to a road and some bridges, at negligible cost. But the indicators of erosion show that the soil has been melting away like sugar, and has been for years. How to measure that damage, and how to repair it, is something to be concerned about. It is probably true that the Mt. Pleasant flood, and all the other floods that have occurred in the past, represent no more than a small part of the real cost of accelerated erosion on the Wasatch Plateau. What the total cost will be we have as yet no way of knowing. The larger part of the bill has still to be rendered.

Range trend and the Mt. Pleasant flood: It is not to be assumed that efforts have not been made to rehabilitate the Mt. Pleasant watershed. About the time the present Manti National Forest was set aside in 1903 grazing by sheep was prohibited. Cattle were allowed to graze the watershed, however, and since 1927 the range has again been grazed in common by sheep and cattle. Use has been reduced both by shortening season and permitting fewer livestock, but the reductions appear to have been made so gradually, and after conditions had become so extreme that they have not been very effective in bringing about improvement.

The earliest record of vegetation is contained in the 1913 range survey. A careful comparison of this with another survey made in 1936 provides a picture of vegetal change on that part of the drainage from which the flood came.

The most significant and widespread change is a decrease in the proportion of the annual knotweed (Polygonum douglasii), an indicator of denuded soil. In 1913 knotweed was, with sweet sage, the most abundant herbaceous plant on the range, averaging 8.3 percent of total vegetation, and in one type making up as much as 40 percent. In 1936 it made up one half of one percent--still too much, perhaps, but the reduction is so great that a definite increase in density of perennial vegetation is indicated. The localized invasion of another annual, tarweed (Meda glomerata), indicates, however, that certain parts of the watershed may be as poor in protective vegetal cover now as in 1913. Tarweed was absent in 1913; by 1936 it made up 1.8 percent of total cover and ran as high as 20 percent in one type.

Changes in other species are marked in some instances. For example, tall larkspur (Delphinium barbeyi) increased from 1.8 to 6.0 percent of the cover and red elder (Sambucus racemosa) from 11.8 to 16.8 percent. On the other hand, niggerhead (Rudbeckia occidentalis) decreased from 5.1 to 3.6 percent, and yarrow (Achillea lanulosa) from 4.0 to 1.8 percent. Taken all together, changes in perennial species suggest that there had been perhaps a little improvement in vegetal composition from a forage standpoint in the 23-year period between surveys.

When this evidence is considered in relation to the much weightier evidence of continuing and current soil erosion--for several of the erosional indicators of bad range condition also indicate emphatic downward trend--it is clear that scant progress has been made during the last 40 years. In fact, a realistic view would be that, while we have been marking time, or perhaps gaining a trifling advantage in vegetal change, we have lost so much soil that the potential vegetal productivity of the land is greatly reduced. If this be true, the job of rehabilitation today is likely to be a great deal more difficult and costly than it would have been 40 years ago.

We have already published evidence, on a small plot scale, to show that soil deterioration may proceed apace even while and after improvement in vegetation occurs. The Mt. Pleasant flood, together with the evidence* of long-continued accelerated erosion before it, is a powerful verification of this thesis.

Condition and trend studies: After the condition and trend manuscript is revised and published (see below), the general principles of judging condition and trend on subalpine range in this region will have been outlined so far as present knowledge allows. Further progress in development of principles, particularly in the use of plant indicators, will require detailed information on the ecology of specific types. For a beginning the successional studies that were begun by Sampson and that have been carried forward in recent years, will be completed. As funds permit, other specific types will be investigated throughout the region. An attack on the aspen type and its subtypes has been undertaken by the Utilization Standards work project, as discussed elsewhere in this report.

During 1946 field work on the ecological-condition study was devoted to making comparisons between relatively undisturbed areas of subalpine range on the Wasatch Plateau and nearby grazed range, and to studying soil profiles. Certain changes in vegetal composition as a consequence of class overgrazing have become increasingly clear. A concept of minimum density of cover has emerged from these comparisons--about 50 percent well-dispersed vegetation and litter--which checks closely with independent observations by the Influences Project on the effects of vegetation on infiltration. This and other observations on range condition made during the past year are being incorporated in the condition and trend manuscript.

Completing revision of the condition and trend manuscript for publication is the first priority job of the summer-range work project, and should be accomplished this winter. Field work of the project during 1947 will attempt to bring to completion the ecological-condition survey of the subalpine zone of the Wasatch Plateau.

Increase Plant Cover

The ecological studies referred to in the last paragraphs relate directly to the problem of increasing plant cover, since it is through an understanding of ecological relationships that increase in plant cover can be brought about by management.

Plot studies in the vicinity of the Great Basin Branch Station give considerable information on changes in plant cover in response to changes in rate and class of stocking. These studies are being combined with more extensive observation in the subalpine zone of the Wasatch Plateau, as mentioned in the last section, in order to bring up to date the story of grazing and plant succession in this subalpine type. Thus, research effort at this Station on the problem of increasing plant cover parallels and is part of ecological research on indicators and plant succession, outlined above.

Evaluate Biotic Influences

The relation between livestock and big game is being taken up elsewhere in this report, since it is a problem which affects spring-fall and winter range, as well as summer range. A graduate ecology student of the University of Utah, Irving B. McNulty, was employed during the summer of 1946 as a collaborator to study the ecology and life history of bitterbrush (Purshia tridentata) in central and southern Utah.

Two salient results of McNulty's study are that bitterbrush normally produces seedlings every year, or at least every few years, and that bitterbrush plants are rare in age classes younger than about 20 years on most grazed ranges. The truncation of age classes varies considerably with locality and intensity of grazing by livestock and game. These facts are important in judging range condition and trend. They point unmistakably to overgrazing rather than weather or other influences as the cause for lack of young bitterbrush plants. And they help orient future research on bitterbrush by defining the critical factor in perpetuation of this forage--survival of young plants under grazing.

Another biotic influence on summer range, which is subject to considerable debate, is the pocket gopher. About the pocket gopher two questions are commonly raised: What part does he play in the formation and erosion of mountain soils? To what extent is he a competitor with grazing animals for forage?

A discussion of the first question, on the basis of several years' observations in the subalpine zone of the Wasatch Plateau, was published in the April 1946 number of *ECOLOGY*. Briefly, the findings are that the pocket gopher is a natural agent in soil formation and normal geologic erosion. He is not a primary cause of accelerated erosion, but does augment accelerated erosion greatly on ranges where the plant cover has been depleted and infiltration capacity of the soil reduced in consequence of overgrazing.

As for the second question, on competition for forage with grazing animals, no conclusions have yet been reached. A cooperative study was undertaken on this question with the Fish and Wildlife Service in 1941. An enclosed 4-acre area was set up on half of which pocket gophers have been trapped out. A weight inventory of vegetation was made in 1941, and a second one was made in 1944. From the analysis of these data, no significant trends could be detected.

What remains to be done on the pocket-gopher question may be as broad and long as the Intermountain region, for investigations to date have been limited strictly to part of the Wasatch Plateau. How widely applicable the answers found there will be is something that remains to be determined. For the coming year, limitations in funds and personnel will permit only continued maintenance of the enclosed study area and extensive observations on pocket-gopher ecology.

Analyze Problems of Mountain Range

This heading is different from the preceding three in that it does not seem to point to an immediate administrative need, but, rather, to a specific research need. Actually, it does both. A comprehensive knowledge of summer-range problems, lacking in any degree of detail at the present time, is essential to a research attack that will be of maximum utility to national-forest administration. As an example, consider the foregoing comments on the uncertainty as to the extent and seriousness of the pocket-gopher question in the region. Again, a research attack by broad range types, mentioned earlier, is necessarily based upon extensive knowledge of what types there are, and of what features of each are in most need of study.

A region-wide problem analysis for summer range is not easily made, and has not been made (at least during the last decade or two), for three reasons. First, mountain ranges are mostly hard to get to and to cover; the inspection of even a small piece of range requires a good deal of time. Second, mountain range is extremely variable, its character in one spot being wholly different from that in another only a few miles away, so that an adequate inspection of mountain range in the Intermountain region is a major undertaking. And third, work project effort has largely been confined, in part by lack of funds, to studies already under way in the vicinity of the Great Basin Branch Station. The field work done by Ellison in 1942, in connection with his and Croft's study of range indicators, was the first opportunity, at least in recent years, to acquire an extensive picture of national forest range conditions and problems. It is planned, as one result of the reorganization of the range research division of this Station, to develop a problem analysis of summer range. This problem analysis will necessarily be built up, as opportunity for systematic observation occurs, over a period of years, because a full schedule of going work, plus limited funds, continue to restrict project activity.

Utilization Standards

The Problem

How much of the forage growing on western ranges can livestock use without destroying the soil and its plant cover? This, broadly, is what the administrator of these range lands must know.

He does know that if stock use all the forage year after year, the better plants disappear and the soil soon washes or blows away. On the other hand, he knows that the users of his range are pressed for feed and usually need all they can get. How much can he allow them to have and still preserve the resource?

This Station has under the Utilization Standards Project attempted to answer specific questions such as these: What are the means of measuring utilization? What are the responses of individual plants to herbage removal? What are the effects of various range sites and conditions on the physiological functions of cropped plants? What are the methods and dimensions that can be used in evaluating range condition and trend? And what are the relationships of condition and trend to past, present, and future utilization of the forage?

Some of these questions concentrate on individual plants or plant species. Most require consideration of the range as a complex plant community, including the individual plants. Knowledge of the plant community and its environment provides the framework into which studies of individual plants or plant species can be fitted.

Past Work

Various methods of measuring utilization have been developed at several forest and range experiment stations. Study of the stubble height method by Clark showed that the amount of stubble left on grazed plants was not a good index to percentages of volume taken, since growth form of plants on central Utah's summer ranges was highly variable. The weight estimate by plot method of Pechanec and Pickford was considered better.

Responses of individual plants to herbage removal have had considerable attention. McCarty and Price made physiological studies of the march of carbohydrates in many widely distributed species. Clark's study on spring grazing of wild hay meadows near Big Piney, Wyoming showed that the total amounts of forage derived as hay and grazing from spring-grazed meadows was greater than that from hay cut alone. Also, the protein content of hay from grazed meadows was greater than that from ungrazed ones. An exploratory study on the relation of plant vigor to utilization was set up on the Wasatch Plateau in 1938.

The community aspects of the problem have received less attention. However, Sampson's early determinations of percentages of allowable use on isolated plants soon had to be modified. Forsling and Storm established that there

must be a decrease in proper use factors of palatable species when these occur thinly scattered in a stand of an unpalatable plant such as oakbrush. That is, allowable use is not a constant value for a species regardless of where or how it grows, in spite of the fact we have and use tables of "proper use." The palatable species, those considered "key," must be selected in relation to the structure of the plant community.

Sampson's early work on plant succession in relation to range management was the first consideration of plant communities as they determine, and are determined by, range utilization. It was the first work on condition and trend. Preliminary attention by Clark under the Utilization Standards Project to range condition and trend resulted in the Intermountain Range Utilization Handbook in 1939. As noted, the main effort of the project was then turned toward the study of individual plant responses.

Analysis of the plant vigor in relation to grazing study shows that smaller plants tend to have a greater proportion of their herbage removed than larger plants. That is, on the percentage basis commonly used for measuring utilization, small plants are the more heavily utilized.

Preliminary analyses of the data on plant vigor in relation to site factors and utilization corroborate the evidence on greater use of small plants, and show that mortality of heavily grazed plants on severe sites is very high.

Utilization in the Aspen Type

All the plant types on the western range need utilization study. The Utilization Standards Project, however, has only very limited funds and personnel, and therefore, its effort must be concentrated to be effective.

The aspen type is advantageous for detailed community studies leading to conclusions on condition and trend. It is a widespread type throughout western United States. Although little ecological work has been carried to completion in the type, a great deal of miscellaneous information has been accumulated. Not least are the data from the Utilization Standards Project on the relation of site and utilization to plant vigor. Also, scattered and generally neglected study plots were established by Administration in the type three decades ago. Aspen stands promise great returns in increasing grazing capacity. Whether this improvement should be made by allowing natural secondary plant succession to take its course or by artificially reseeding is a question not answerable without knowing what natural plant successions there are in the type and what the type's potentialities are in various degrees of condition. How long will such secondary successions take in relation to the present very variable herbaceous covers which differ both by subtypes and by degrees of condition within subtypes?

Three main problems can be separated in a consideration of the aspen type. First, what is the type and of what subtypes does it consist? Costello (Conference on methods and techniques relating to national forest range and wildlife management, Denver, 1944. IIIC, p. 6) mentions eight subtypes commonly found in range type 10, aspen, presumably in R-2. Many of these and several others may be found in R-4. After we have differentiated the subtypes, we can evaluate the differences between them for management. Certainly potentialities of the subtypes are different. Key species are different. And management differs according to what is being managed.

Second, what are the changes in the type? We suppose generally that aspen stands are temporary. What does this mean in terms of years? And if an aspen stand is economically advantageous, how can we thwart natural plant succession and perpetuate the stand? Finally, what are the mutual relations of changes in the type with the neighboring types, such as lodgepole pine, spruce-fir, alpine meadow, mountain brush of several kinds, sagebrush, and grassland?

Third, what are the changes in the subtypes, classified according to ground vegetation, under the aspen overstory? These are the shorter term changes which directly determine range condition and affect grazing capacity. They are of immediate, practical significance.

1946 Work

Jack Major was assigned to the Utilization Standards Project in March upon his return from the Army, and was allowed educational leave to take graduate work in September. The work year for this project has therefore been very short. Compilation has been extended, however, by hiring Rudolf Glauser, Agricultural Aid, SP-4, during the present winter.

During the field season of 1946 Major relocated and reexamined several old administrative study plots on the Cache and Caribou. He had insufficient time to relocate those on the Wasatch, Uinta, Ashley, Fishlake, or Dixie, as had been planned, but was able to make general observations in the aspen type on parts of these forests. Much of the field season was taken up in becoming acquainted with the plant vigor study and delving into the data accumulated in past years by Clark.

In general the results from the plant vigor study have been negative. The study was based on the expectation of obtaining a wide range of intensities of utilization and thereby relating plant response to utilization intensity. Under the virtually uncontrolled grazing on the study areas, however, utilization has not had a sufficiently wide range; nearly all the plants have been utilized very heavily each year. The population distributions are therefore so skewed that results of statistical tests are questionable.

1947 Work

During 1947 Major will complete the two studies in the aspen type begun in 1946. These are to (a) recover old administrative study plots and (b) continue the extensive survey of the aspen type and forage potentialities of its subtypes in Utah. He will also complete the unfinished business of the plant vigor study, reviewing Glauser's compilations and analyses with the object of publishing the results summarized in the last paragraph.

Spring-Fall Range

The spring-fall ranges of the Intermountain region form an important tie in the yearly pattern of migration from winter feeding grounds to high summer ranges and back again. Totalling about 50 million acres, they occupy much of the vast Snake River plains of southern Idaho, and the foothills and the lower slopes of the mountains in the Great Basin and Colorado River drainages. The climate of the spring-fall range territory is generally mild with average annual precipitation varying from 8 to 20 inches. Most of the soils are productive.

Much of the spring-fall range is covered with big sagebrush (Artemisia tridentata), but there are also extensive acreages, where sagebrush has been destroyed by fire, now occupied by nearly pure stands of cheatgrass (Bromus tectorum). On areas which have not been abused by overgrazing and indiscriminate burning, the understory consists of mixtures of grasses and weeds.

Because they are closer to farms and settlements than either summer or winter ranges, and because grazing on summer and winter ranges is generally limited by regulation, spring-fall ranges, many of which are in private ownership, are highly vulnerable to abuse. Today they produce only a small part of their potential forage, and are considered the critical part of the year-round forage picture.

Several important problems exist which, if solved, would bring spring-fall ranges more nearly up to full productive capacity. These problems include: (1) increasing the productivity of sagebrush range by reducing sagebrush; (2) evaluating cheatgrass for spring-fall range; (3) balancing stocking against forage supply; (4) determining proper distribution of use; and (5) determining proper season of use.

While these general problems have been recognized for years, it is essential that the many specific problems they embrace may be properly evaluated. Accordingly a problem analysis of range use in the upper Snake River area is being undertaken. This work is second in order of priority only to that of analyzing the accumulated data in the files at the Sheep Station. With the increase in junior-grade personnel resulting from additional appropriations to the Upper Snake River research center this past year, both tasks can be carried on more effectively than heretofore.

Increase Productivity of Sagebrush Range

On many millions of acres of spring-fall range, sagebrush has become so dense that little palatable forage is produced, and much of that which is produced is unavailable. Moreover, in the dense brush there is considerable loss of wool and lambs. Therefore one of the most important steps in spring-fall range improvement is eradication of sagebrush. Beginning in 1932, work was begun in eastern Fremont County, Idaho, in cooperation with the State of Idaho and the Fremont County Woolgrowers Association, to determine the effects of burning on sagebrush and subsequent range productivity. In 1936, similar studies were begun at the U. S. Sheep Experiment Station. These studies (USDA Farmers' Bulletin 1948, "Sagebrush Burning--Good and Bad,") show that by controlled burning of areas having a reasonably good cover of perennial grasses and weeds, with proper grazing management following burning, grazing capacity can be increased 70 percent or more. On the other hand, uncontrolled burning and unrestricted grazing result in little or no improvement and often in damage to the range and other property.

In June 1946 Ellison and Holscher made a careful inspection of the Fremont County burn. The most striking change has been an increase in bitterbrush (Purshia tridentata) since 1935. Plants which appeared dead at that time have since sprouted from the roots and are now 5 to 7 feet across and 3 feet high. Young plants occur on all parts of the burned range. Some reinvasion of sagebrush is taking place. Most young sagebrush plants are found to leeward of areas that were not completely burned, where parent plants continued to produce seed. In a large area of some hundreds of acres that was burned clean, sagebrush plants are exceedingly few, perhaps one plant to 5 or 10 acres. This illustrates the desirability of a clean burn to prevent reinvasion of sagebrush. Changes were also noted in abundance of various species of grasses and herbs. It is clear that a resurvey will yield valuable information from both ecological and range management points of view. Such a resurvey is being planned for the summer of 1949.

Methods of removing sagebrush by mechanical means have also been devised. These include wheatland plowing, raking, harrowing with a self-clearing harrow, ripping with a road ripper, and rolling with a spiked roller. Each of these methods results in a reasonably good kill of sagebrush, but none in a total kill. Costs by these methods of eradication are considerably higher than by burning. Results of this work on mechanical eradication have been made available in Research Note No. 10.

Further research on sagebrush burning is necessary to ascertain in detail the effects of repeated fires on individual species and on the soil, and to observe long-time trends under good management after burning. Two specific questions are: What is the reason for heavy stands of sagebrush following fire in occasional years, even under best possible management? The answer to this question may reveal how such mischances can be avoided. And to what extent and how fast will sagebrush reinvasion stands of herbaceous species? In the numerous situations where burning is not possible or where it is not advisable, some mechanical treatment is required. Much more study of methods and equipment is needed to devise effective, economical techniques

of mechanical sagebrush removal. There is also need for active program of demonstrating controlled burning and proper management to those who plan to eradicate sagebrush by fire.

A field day was held at the U. S. Sheep Experiment Station on May 24, 1946, in cooperation with the Bureau of Animal Industry. Nearly 300 people, from 12 states, reaching from Minnesota, Iowa, and Missouri to California, were in attendance. The program was confined to certain phases of sheep improvement by the Bureau of Animal Industry and to sagebrush burning and reseeding by the Forest Service. Particular attention was given to How, When, and Where to burn and management practices necessary to secure lasting range improvement.

Evaluate Cheatgrass for Spring-Fall Range

Cheatgrass, introduced to the Intermountain region shortly before 1900, is estimated to be the principal species on about 7,000,000 acres of land in the region. In a range survey made on 3,746,436 acres in south-central Idaho, it was found that cheatgrass was the dominant herbaceous species on 1,623,106 acres.

Cheatgrass is now being used extensively by both sheep and cattle growers for spring range. One stockman in southwestern Idaho deliberately spread cheatgrass over his sheep range in order to obtain early spring feed. Yet cheatgrass has certain characteristics which make its presence a management problem. After the fruit matures and the plants become dry, it is extremely inflammable. During favorable years it produces an abundance of herbage, but in adverse years it may produce only about one-tenth as much as in good years. Unless rainfall is favorable so that cheatgrass germinates and grows in the fall, it is of little value as fall sheep feed. These and other factors contribute to the problem of cheatgrass as a permanent type for spring-fall range.

Because it has both advantages and disadvantages, depending on where it occurs and from what standpoint it is viewed, considerable study is needed to evaluate cheatgrass adequately. Studies need to be made of the use now being made of cheatgrass ranges by both cattle and sheep to determine how well cheatgrass is serving as forage. How devastating to the forage supply is fire and how great is the danger of damage to other values? How reliable is cheatgrass production from year to year? How effective is cheatgrass in protecting and preserving soil? How do cheatgrass ranges compare in animal production with native ranges in good condition and with reseeded ranges? If, after these and similar questions are answered, it is decided that cheatgrass is a valuable range type under certain conditions, studies will be needed to determine the best ways of managing cheatgrass range for maximum returns.

Although a project has never been set up to study the cheatgrass problem on spring-fall range, some knowledge about it has been gained incidentally to other work. A report on the present state of knowledge of this species, submitted to the JOURNAL OF FORESTRY has been returned for revision by Pechanec and Hull. During 1945 comparative phenological and clipping studies were continued on cheatgrass and crested wheatgrass on unburned range.

No intensive studies of cheatgrass are planned for 1947. The incidental studies made in the past will be continued, and the cheatgrass problem will be considered in the problem analysis being undertaken by Hoischer.

Balance Stocking with Forage Supply

One important reason for the depleted condition of spring-fall ranges of the Intermountain region is that far greater demands are made upon the forage than can possibly be met. These ranges have been repeatedly and closely grazed year after year at the same season. Stands of palatable perennial herbaceous species have been reduced, allowing sagebrush and other species of low palatability to spread and occupy the ground.

At the U. S. Sheep Experiment Station pasture studies have been conducted since 1924. Two adjoining pastures, one heavily grazed in spring and in late fall and the other heavily grazed only in late fall, show remarkable differences in species composition and grazing capacity. The fall grazed pasture has little sagebrush and a great abundance of weeds and grass. The pasture grazed heavily both spring and fall is becoming so thick with brush as to make difficult its use by sheep.

Beginning in 1932 three intensities of sheep grazing have been studied and have shown definite trends in vegetation. The spring-fall management manuscript, by Pechanec and Stewart, has been sent to Washington for final editing as a Farmers' Bulletin.

The intensities of stocking being applied at the U. S. Sheep Station should be continued and studied, with a similar objective on spring-fall sheep range in Utah, to determine ways of balancing forage supplies with live-stock numbers. So far, research has been done mainly on range in good condition. Much further research is needed to determine the rates of stocking necessary to bring deteriorated spring-fall ranges back to their potential productive capacity.

Nothing has been done to study the problem of balancing forage and cattle numbers. It is estimated that 50 percent of the use of spring-fall ranges is made by cattle. Many of these cattle are run yearlong on this type of range. The ranges used by cattle are deteriorated and research is needed to learn how to bring them into productive condition.

During 1947 pasture treatments will be continued at the U. S. Sheep Experiment Station. Special effort will be made to tie down more closely indicators of trend in relation to rate of stocking. The problem of cattle management will be further studied preparatory to outlining a research project.

Determine Proper Distribution of Grazing Use

Many ranges are overgrazed and some ranges are used less than they might be because livestock are not distributed uniformly. The chief causes of uneven distribution of grazing are rough topography, lack of or poor distribution of water, and use of the wrong class of stock on a particular

range. Topography, of course, cannot be altered to suit grazing needs but it seems likely that management practices can be devised which will do much to relieve the range distribution problem.

No research has been done on spring-fall range to aid in solving the distribution problem. Perhaps the most fruitful attack on this problem involves the distribution of water. How much can improving distribution of water aid in improvement of spring-fall ranges? Where is water development economically feasible? Where it is not feasible, what are the possibilities for hauling stock water? A research project to determine the practicability of water hauling is of first line importance in a spring-fall range improvement program. Other studies might include the effect of salting and riding on distribution and determination of the type of range best suited to uniform use by different classes of livestock.

No work on livestock distribution is planned in 1947.

Determine Proper Season of Use

Although the name "spring-fall" indicates season of use in a broad sense, management of these ranges can be improved by a more detailed breakdown within the spring season. In the migration system of grazing which is followed on the Snake River Plains by sheep, it is common practice to graze the same range at the same time each spring. This practice undoubtedly places certain parts of the range at a disadvantage. Studies at the U. S. Sheep Experiment Station demonstrate that clipping at the time balsamroot (Balsamorhiza sagittata) blooms and bluebunch wheatgrass (Agropyron spicatum) comes into head is much more injurious than at any other time in their life cycles. Ranges grazed at that stage of development each year are obviously handicapped. At this most critical stage wheatgrass averages 5.4 inches in height. Since many spring-fall ranges are not grazed until wheatgrass is 4 to 6 inches tall, these studies indicate that it may be advantageous to graze ranges having firm, dry soil earlier than has previously been supposed.

The pasture grazing studies at the U. S. Sheep Experiment Station are designed to test effects of rotational and rotational-deferred systems. Results of these grazing treatments are not clear-cut as yet but there is some evidence that grazing under the rotation-deferred system is too severe even when complete rest is granted a pasture one year out of every four. The present studies need to be supplemented through comparison--by extensive observation, at least--with the continuous migration system practiced by sheepmen. Also, since many cattle outfits use spring-fall range year-long, we need to determine whether this is good range practice or whether a shorter or broken season would be better.

During 1947 grazing treatments on the pastures will be continued. Special effort will be made to find indicators of the effects of these treatments which are capable of wide application.

Winter Range

Some 4 or 5 million sheep and 250,000 cattle graze on the winter ranges of the Intermountain region for a period of 5 to 6 months each year (November to April). These animals represent about 80 percent of the range sheep and 20 to 30 percent of the range cattle within the region. Because winter ranges constitute a necessary part of the yearlong grazing operation, their value depends on integration and use with other seasonal ranges.

The major winter range areas of the Intermountain region, totalling about 65 million acres, lie in great blocks in eastern and western Utah, central and southern Nevada, southwestern Wyoming, and portions of southwestern Idaho. These areas are characterized by scant precipitation and low forage production. Livestock depend on snow for water, and a large part of the winter range cannot be effectively grazed except when snow is available. About 70 percent of the vegetation, growing in broad open valleys and on lower foothills, belongs to the salt desert shrub formation. The remainder, on higher ground, consists of sagebrush and pinyon-juniper.

Chief problems of the winter range are to: (1) balance stocking with forage supply, (2) predict forage supply in advance of grazing, (3) secure more uniform distribution of livestock, (4) establish widely applicable criteria of range condition, trend, and utilization, and (5) determine nutritional values of forage species and need of supplemental feeds. The second item is really part of the first, but because weather plays a very important part, often limiting forage production drastically, the problem is set out for special consideration.

In 1933 a tract of 55,000 acres of typical winter range in western Millard County, Utah was set aside for experimental purposes. Fenced pastures were constructed, a well was drilled, and headquarters for the Desert Branch Station were established to provide facilities for studying problems of winter range management.

Balance Stocking with Forage Supply

Some of the better sites on valley slopes or mountain foothills on the winter range produce as much as 700 pounds of air-dry herbage per acre while others in the "scabland" or alkali bottoms produce only about 50 pounds. Range in good condition may produce two to three times more forage than overgrazed range in poor condition. These wide fluctuations in production together with differences in quality of forage produced often make some areas 10 to 20 times more productive than others.

General surveys and detailed plot studies have revealed that most winter range is capable of producing far more forage. In comparison with protected or lightly grazed range, plant cover on large areas of heavily grazed winter range had been reduced 34 percent and forage yield decreased 62 percent as a result of overgrazing. Results from the exploratory surveys are published in the Western Range (S.D. 199) and in the JOURNAL OF AGRICULTURAL RESEARCH, 1940.

It has been demonstrated that heavily grazed winter range, when protected from grazing or grazed only at moderate intensity, recovers rapidly. Recovery is as rapid under moderate use as under total protection. On 30 to 40 enclosures established throughout winter ranges of Utah and Nevada and on moderately grazed areas at the Desert Range Branch Station, plant cover, herbage yields, plant vigor, and reproduction show marked increases. Forage production on these areas after 5 to 7 years is 1.5 to 2.5 times greater than on adjacent heavily grazed areas.

Investigations of the effects of light, moderate, and heavy stocking on vegetation and sheep were started in a series of pastures at the Desert Range Branch in 1935. During 10 years' treatment total plant cover under heavy grazing decreased 20 percent in comparison to that on moderately and lightly grazed areas. In addition records on sheep have been obtained from two herds, one wintered on moderately grazed range and the other on heavily grazed range. Sheep kept on moderately grazed range throughout the winter remained in 8 pounds better flesh, produced 1 pound more wool per head, produced 7 to 10 percent more lambs, and suffered 5 to 11 percent less death loss than those on heavily grazed range.

Additional experimental work is needed on other subtypes, particularly black sagebrush in the foothills, to evaluate effects of grazing on these subtypes and to determine how information obtained from the pastures in shadscale-winterfat types can be extended to other areas. To date studies of balancing livestock and forage have been confined to sheep. Later studies should be expanded to evaluate cattle grazing.

In 1946, 26 study areas distributed over Nevada were reexamined, giving a record of the effects of 10 years' protection in comparison with grazed range. These data have not yet been compiled and analyzed, so the results cannot be summarized here. Within the coming 2-year period it is planned to supplement them with observations on winter utilization and to prepare a cooperative publication with the University of Nevada.

The manuscript "Management of Winter Sheep Ranges in the Intermountain Region," has only recently been returned from the Board of Review. Hutchings and Stewart are now revising it.

During 1947 enclosures and pastures will be maintained, and grazing treatments will be continued on a maintenance level with a minimum of plot work. The principal effort will be directed toward getting into publishable form information already collected.

Predict Forage Supply in Advance of Grazing

Much of the herbage growth on winter range is produced by the end of September and the forage supply for the coming winter can be determined from plot yields. Records obtained at the Desert Branch Station show that there is a close correlation between forage yield and precipitation received during the preceding 12 to 15 months. These facts suggest that precipitation may some day be used as a reliable index to forage supply.

The first need is annual forage inventories on numerous areas throughout the winter range over a period of years. These can be used currently to inform stockmen throughout the region as to the amount of available forage prior to the time they take their livestock to them. These inventories after several years' record, correlated with precipitation, can be used to forecast production. In years of low production stockmen will then have ample opportunity to adjust livestock numbers or provide additional feed to augment forage on the winter range.

Phenological studies were begun at the Desert Range Branch in 1935. Observations were made on seven major forage species at weekly intervals throughout the spring and summer growing period. In addition supplemental data were obtained on other species at irregular intervals and on random sites within the experimental area. During 1946 these limited records on plant growth were discontinued for want of help.

This study should be enlarged to include all the major forage species and expanded to several locations in order to obtain information on growth and requirements of the various plants and their relationship to weather, soil, and associated species. In addition information on physiological plant processes--plant food production, storage of food reserves, and the relationship of these to grazing--is highly desirable.

In 1947 weather records at headquarters will be maintained.

Secure More Uniform Distribution of Livestock

One of the major drawbacks connected with use of winter range is the long migration to the desert in fall, and to lambing and summer ranges in spring. These migrations, often of 100 to 200 miles, over rugged, dry country, deplete the narrow driveways and lower the vitality of sheep. Migration hazards of storm, insufficient forage, insufficient water, and areas of poisonous plants, cause heavy death losses especially in spring when ewes are poor and heavy with lamb. Almost one-half the winter losses occur along migration routes. The trailing problem has been outlined by Hockmuth, Franklin, and Clawson in U. S. Department of Agriculture Circular No. 624.

After they come on the winter range, livestock are often poorly distributed, especially during dry periods when snow is scarce. At these periods they are confined to localized areas near wells or snow, or are trailed repeatedly to and from snow and water. In early spring sheep are concentrated around strategic shearing corrals, sometimes in vast numbers. Overgrazing and trampling under such circumstances are very severe.

Experimental studies to determine the feasibility of hauling water to sheep on winter range were begun at the Desert Range Branch in 1936. Hauling water proved beneficial and economically feasible. Long trails to water or snow were eliminated and trampling injury was reduced. Livestock were kept on fresh feed because troughs were frequently moved to new locations to control grazing and provide for uniform utilization. A preliminary report on water hauling, "Drive the Water to the Sheep" was published in the April 1946 issue of the NATIONAL WOOL GROWER.

Studies are needed to determine the optimum number of watering places, number of animals, and number of times they should use a given watering place. The effects of trailing to and from water, on both range and animals, should be more adequately evaluated. Studies are also needed to determine the effects of shearing corrals on both range and sheep.

Plans for 1947 do not include studies on livestock distribution, except as observations may be made incidentally to other work.

Establish Widely Applicable Criteria of Range Condition, Trend, and Utilization

Blanket stocking factors obtained from the Desert Branch studies cannot be applied directly to the entire winter range. Criteria of proper utilization have been obtained from intensity studies in the Desert pastures, expressed in terms of stubble height. It may be possible to apply minimum stubble height standards to other range areas with some modification.

Factors beside utilization must also be considered. In general it is known that winter ranges in good condition have a relatively high density of plant cover, the better forage species are thrifty and productive, many young plants of the better species are present, and soil is essentially stable except during torrential storms. But such knowledge must be related to specific vegetal types to be of maximum use. Types, too, should be classified by condition so that utilization standards can be set up for each type-condition class.

Much of Hutchings' effort during the summer of 1946 was devoted to making type-condition descriptions and photographs for an illustrated guide on range condition and utilization of the major winter-range types. Work during 1947 will continue on this manuscript, which is second in priority only to the management manuscript now being revised.

Determine Nutritional Values of Forage Species and Need of Supplemental Feeds

Winter ranges are grazed during the period when most forage species are dormant and when the nutritional value of many of the forage plants, especially herbs and grasses, is low. Even on winter range where animals have an ample quantity of forage, they frequently lose weight, especially when grasses and shrubs are exceptionally dry. Preliminary studies by the Utah State Agricultural College indicate that winter range forages are low in protein and that protein supplemental feed may be desirable.

A study is needed to make chemical and digestibility analyses of the major species at intervals throughout the winter. Also studies are needed to determine the value of various supplemental feeds such as cottonseed cake, corn, pellets, etc., and to determine the period to feed, amount to feed, effect on sheep, and effect on range.

At present the Utah State Agricultural College is obtaining samples of certain forage species at intervals through the winter of 1946-47, for chemical analysis. They plan, also, to conduct supplemental feeding trials during the winter of 1947-48. The facilities of the Desert Branch Station are being made available to the College for this work, but aside from this the Intermountain Station is not participating actively in it.

BIG GAME RANGE

In the Intermountain region ranges used by big game play an important role in the social and economic welfare of the people. On national forests alone an estimated population of 340,000 deer and 40,000 elk provided recreation for approximately 130,000 hunters in 1946. Although recreational values are difficult to evaluate, big game is recognized as a very important recreational asset. In this region in 1946 a great many of the visits of over 3,000,000 people to national forests were enriched by the pleasures of observing big game.

Most of these same ranges provide essential forage for livestock upon which farming communities throughout the region depend.

A third major resource of range used by game is water, the life blood of western agriculture and often the limiting factor in the development of industry.

The use of these three major resources of range used by game must be correlated and managed on a sustained yield basis if increasing social and economic demands of the region are to be best served.

Deer in the Intermountain region graze practically all national forest and national park lands and large acreages of Taylor grazing, state, and private lands. The high mountains, chiefly in national forests interspersed with state and private lands, are the centers of the major deer herd units and supply summer forage. The foothills of these mountains, together with adjoining hills and spur ranges, furnish winter food and cover. Some of the winter range lies within national forests but much of it is on private, state, and Taylor grazing lands.

Elk occupy many of these same ranges although their distribution is much more limited.

Big game in this region passed through a period of exploitation from early settlement until about 1907. Elk and antelope were exterminated from much of their original range and deer were reduced to small numbers. A period of conservation and protection followed. Game populations started upward under the buck law, short hunting seasons, and closed areas. During the past 20 years with restricted hunting, predator control, and goodly numbers of breeding stock, deer have made remarkable increases. Elk in some cases have done likewise and their restoration to many of their original ranges has been very successful.

These large numbers of game animals added to ranges already heavily stocked with sheep and cattle have created serious problems in the management, conservation and wise use of the basic resources of big game-livestock range. While big game numbers have been climbing, heavy reductions in sheep and cattle have been made to relieve overgrazed range. Livestock permittees resent such action and insist that game numbers should also be balanced with the forage supply. Overpopulations of big game on private land has also met with resentment. Many sportsmen on the other hand believe that heavy grazing by livestock is interfering with the game interests of the region. Because they are inadequately informed and have not fully realized what watershed values are involved, the majority of water users show little aggressive interest in the issue.

Game for recreational use of thousands; livestock to support a basic industry of the region; water for all--these are the major products of range used by big game. How can big game-livestock range be managed to produce the maximum combined game and livestock crop and conserve the watershed values? To gather facts and develop principles and concepts to meet this question is an urgent job for research.

Previous Work

The Intermountain Forest and Range Experiment Station, in 1939-42, cooperated with Region 4, Utah State Fish and Game Commission and Utah State Agricultural College in preliminary deer range studies. Basic data were obtained within a fenced deer pasture on forage value and preferences, carrying capacity and census methods. This work ended when a fire destroyed the fences in 1942.

Rasmussen, formerly at the Utah Wildlife Research Unit, has conducted research on the life history and management of the mule deer in Utah, and some phases of this work are still in progress. The fallacies of supplemental winter feeding of big game in the Rocky Mountain area have been shown by Rasmussen in Utah, Carhart in Colorado, and Murie in Wyoming. Forage utilization and condition of deer range in the Rocky Mountain area have been studied by Rasmussen in Utah, Hunter in Colorado, Aldous in Nevada, and Julander in Arizona. Methods of making forage inventory on big game ranges have been investigated by Rasmussen in Utah, Schwan and Swift in Colorado, and DeNio in Montana.

Numerous local studies of the food habits of mule deer in the Rockies have been made including the work of Carhart in Colorado, and West and DeNio in Montana and Idaho. Food habit studies of elk have been published by Rush on the northern Yellowstone elk, Goffney in Montana, Young and Robinette in Idaho, and West and DeNio in Region 1, and Roberts in Arizona.

Work accomplished in 1946

At a meeting on September 26, 1946, representatives of the Forest Service (Research and Administration) met with representatives of the Fish and Wildlife Service, Utah State Fish and Game Commission, Utah State Agricultural College, and the Bureau of Land Management to formulate the cooperative aspects of a big game, livestock, and range relationship project. The objectives of the project agreed upon were to gather facts and develop principles and concepts to form a basis for the management of range for the production of big game and livestock and for the conservation of other resources. Two committees were organized: (1) an administrative committee composed of representatives of each agency to handle matters of policy and (2) a project research committee made up of a project leader from each research agency to plan and conduct research. A third committee, advisory in nature, was agreed upon and is to be appointed by the administrative committee. The advisory committee is to represent agencies, organizations, and individuals interested in the resources of big game-livestock range.

Since this meeting a cooperative memorandum of understanding has been formulated by the project research committee and submitted to the administrative committee.

Several ranges were observed in the fall of 1946 to determine existing conditions and to select study areas for preliminary investigations. At present an analysis of the big game-livestock range problem is being made by the project research committee. Information is being compiled from past work to give a picture of problems in Utah, and maps are being prepared showing: (1) vegetal types, (2) land status, (3) numbers of range livestock, seasonal ranges, and known problem areas, and (4) game populations, seasonal ranges, and known problem areas.

Future Work

The Intermountain Forest and Range Experiment Station is primarily concerned with the range phase of the project. Studies on big game range will be carried on (for the present at least) on the open ranges of Utah wherever suitable conditions can be located. Advantage will be taken of existing study enclosures and areas closed to livestock. It is contemplated that further facilities in the way of study plots and possibly pastures may be needed as the work progresses.

Two men, a project leader and assistant, have been assigned full time to the study of big game range. It is expected that funds will be available to employ in 1947 one temporary field assistant. At least two additional field assistants can be employed on the project to good advantage after 1947.

From present knowledge it is expected that major studies will fall into five main problems as follows: (1) problem analysis, (2) big game-livestock food habit relationships, (3) indicators of game range condition, (4) utilization standards for game forage, and (5) carrying capacity of ranges for big game.

Problem Analysis

The phases of the problem analysis already under way as outlined above under "Work Accomplished in 1946" will be continued. It will be the responsibility of the Intermountain Forest and Range Experiment Station to compile and map the data on livestock numbers, seasonal ranges, and problem areas. Field examinations will be made of representative game ranges throughout the state to evaluate range conditions and problems. Forest officers, state game wardens, livestock men, and sportsmen will be interviewed to get their ideas on the problems. When sufficient information and background has been secured study areas will be selected and a comprehensive research program formulated in cooperation with other participating agencies. It is expected that the problem analysis will be completed in 1947.

Big Game-Livestock Food Habit Relationships

The question of the nature and extent of big game relationships with livestock in different combinations, under different intensities of stocking and on different range types and range conditions is little understood. Foraging habits no doubt vary with forage composition, range condition, and grazing pressures. Do livestock compete with game for forage? If so, under what conditions? This issue is being heatedly argued by game and livestock interests of the West. Answers to date are based largely on general observations. Research data are lacking.

The fact that big game use practically all of the livestock summer range in this region and secure a good share of their winter food from private land makes this problem of high economic importance.

Exploratory studies on this problem will be carried on in 1947 to determine suitable methods of study and to secure preliminary information for intensive studies.

Indicators of Game Range Conditions

Within the Intermountain region big game ranges vary in condition from good to severely depleted. The list of overstocked problem areas is growing. Too often administrative game problem areas are not discovered and designated for remedial action until serious depletion is well under way. Furthermore, the results of overstocking are not fully appreciated and corrective administrative action is difficult. The job for research is to develop reliable and usable criteria for judging condition and trend and for detecting administrative problems in their infancy.

Utilization Standards of Important Game Forage

How closely can important forage species be safely grazed? What is the maximum use which will permit recovery and reproduction of weakened plants on depleted range? Answers to these questions are essential in managing game range for maximum sustained production and for the regeneration of many overgrazed areas. Research work along this line to date has been confined chiefly to grasses on livestock range. Results of limited studies on the safe use of browse have varied greatly, and some of the very important species such as curlleaf mountain-mahogany (Cercocarpus ledifolius) have received no attention.

Carrying Capacity of Ranges for Big Game

In the cooperative management of big game where federal and state agencies and livestock and sportsmen's organizations are all involved, it is necessary to arrive at carrying capacities in terms of numbers of game. It is not sufficient to say a range is 25 percent overutilized or underutilized because in formulating management plans and setting up hunting regulations for removals numbers must be specified.

Forage inventory and utilization studies combined with accurate censusing and kill records of game on definite herd units should yield useful information on carrying capacity. It is contemplated that such studies will be made in cooperation with the Fish and Wildlife Service.

The collection of factual data showing the results of overstocking of big game on the productivity of the range and game herd is another job for cooperative research.

RESEARCH IN RANGE RESEEDING

In the Intermountain region grass is twice important. Here, as everywhere, it is valuable as forage for livestock. In nearly all years there is a scarcity of range feed, especially in early spring before the mountainous ranges are warm enough to permit much plant growth. Grass in the foothills and valleys therefore is especially valuable because at lower elevations it makes its earliest and most rapid growth. Grass is also important on the mountainous watersheds where it serves the two-fold purpose of aiding water to percolate into the watershed and of holding the soil against the forces of erosion. Water is so vital in Idaho, Nevada, Utah, and southwestern Wyoming, which constitute the Intermountain region, that any use which diminishes its quantity, makes its flow more irregular, or lessens its quality must be guarded against.

Watershed protection and maintenance are of peculiarly great importance just now in the West. Growing population and increasing standards of life intensify the demand for culinary water of high quality. Reclamation by means of water storage reservoirs for irrigation and for electric power needs all the aid that can be given to prevent a reduction of storage capacity by the silting of reservoirs. Current and prospective industrial developments are also limited by the amount, regularity of flow, and the quality of water available. Water supplies and the condition of watersheds are therefore being scrutinized as never before.

Unfortunately, great areas of range and watersheds bear a plant cover that is greatly deteriorated from overgrazing in many cases, from improper distribution of livestock in others, from destructive removal of timber in still others. In certain localized areas repeated burning has greatly weakened or changed the plant cover. It is on these deteriorated areas that range reseeding can make its greatest contribution. The larger part of deteriorated range recuperates rapidly when grazing is relaxed. On a great number of areas, however, the contribution that reseeding can make is important, because in extensive parts so much topsoil has already been lost that the power to make vigorous revegetation is much lower than it might have been otherwise. On extensive parts of the range and watersheds, recovery by natural revegetation takes place slowly because not enough high-quality range plants are left to furnish seed even when the degree of grazing is considerably lessened. On such lands as are suitable for it, and when competition from other plants is reduced or removed, reseeding is by all odds the quickest and most effective method of obtaining a new plant cover.

Priorities in Program of Reseeding Research

Several years ago when the program of research in range reseeding was just getting under way the following order of priorities set up and rather closely adhered to from 1937 to 1946 may be listed as follows:

A. Ecological location of concentrated research

- I. Sagebrush zone (spring-fall range)
- II. Mountain brush zone (spring-summer range)
- III. Subalpine zone (summer range)
- IV. Salt-shrub "desert" zone (winter range)

B. Procedure within zones

- I. At first concentrate on most productive sites
- II. Make early studies of most critical watershed areas
- III. Later extend investigations to less favorable sites and less urgent forage situations

After a study it was early decided that sagebrush lands in the valley and in the lower foothills presented the greatest need and also afforded the greatest opportunity to increase forage production by reseeding. Reseeding investigations in this zone were therefore assigned first priority because these lands would benefit most from a body of information that might be developed. It was planned that at such a time as accumulated knowledge of reseeding procedures in the sagebrush zone was great enough to establish guidance for an "action" program, research effort should be intensified in the mountainous zone. From the very first, "pilot" plantings were made in all zones. This plan of procedure was followed with good results. Two years ago systematic studies in the mountain brush zone and the subalpine zone were begun and are still being added to.

Because cheatgrass ranges were furnishing considerable volumes of spring forage, they were at first regarded as less urgent cases than deteriorated sagebrush and mountain brush ranges from which little forage could be obtained. A number of pilot plantings, however, had been under way for 5 or 6 years. It is only since 1945 that a program of organized studies was undertaken on ranges occupied by cheatgrass.

Only in the fall of 1946 were we free to begin studies on the low precipitation areas locally designated as salt-shrub "desert" ranges used mostly for winter grazing. It is known that in this zone, which is too dry to support stands of sagebrush, the reseeding problems are more difficult and may not yield so readily to our first efforts.

Findings and Status of Reseeding Research

Brief statements of the findings and conclusions so far reached, are presented in the following paragraphs. At the beginning are two general statements of (a) broad conclusions, and (b), status of progress. After these come a series of more specific findings under such topics as (1) species and strains, (2) time of seeding, (3) methods of reducing competition, (4) suitable machinery, (5) airplane seeding, (6) grazing use of reseeded lands, (7) forage production on large areas, (8) invasion of reseeded stands by sagebrush and rabbitbrush; (9) site rating and classification. At the end is a brief statement of personnel changes.

Broad Conclusions

At least five somewhat sweeping conclusions classified by vegetation zones seem warranted from the research and experience in range reseeding in its present stage, as follows:

A. Sagebrush zone

1. On the better soils in the sagebrush vegetation zone, reseeding when done in the right way, at the right time, and with suitable forage species, produces yields of forage that justify great efforts being applied to reseeding. Yields of from a half ton to a ton of air-dry forage per acre are common, exceeding by 5 to 15 or more times the yield of similar adjacent range not seeded. On a long-time basis forage is produced at remarkably low costs. With 8 to 10 millions of acres of sagebrush in need of reseeding and suitable for such treatment, the possibilities of forage production on these lands are immense.
2. Reseeding is a rapid means of improving deteriorated ranges that are suitable for reseeding and properly handled. By the third or fourth year, most successful seedings have reached nearly full yields.
3. Soils that support large stands of good-sized sagebrush (waist high or taller) are capable of producing satisfactory yields of grass. Such lands may be too steep, too rocky, or too rough to be handled efficiently with machinery, but that is a matter that can be determined by inspection. Soils that support good growth of aspen, chokecherry, snowberry, oak, or maple are most likely suitable for reseeding once the brush is removed.

B. Mountain-brush zone

4. Reseeding on mountain brush lands of good quality has produced even higher yields than those obtained in the sagebrush zone. Several yields of as high as 1-1/2 to nearly 2 tons of air-dry forage per acre have been obtained. Both the precipitation and the soils are more favorable than in the valleys.

C. Subalpine zone

5. With watersheds badly in need of protection, reseeding offers a promising means of restoration. One opportunity is to seed deteriorated subalpine areas on the watershed itself. In some cases much greater results may, however, be obtained by seeding the larger areas at lower elevations that are suitable for reseeding and grazing there the animals that overtax the grazing capacity of the higher watersheds. Certain watersheds are best treated by one method and some by the other.

Present Status of Reseeding Research

According to the priority schedule made several years ago, reseeded investigations in the sagebrush zone have built up a body of information that has permitted us to develop rather reliable instructions for an "action" program in that zone. The Regional Office has gone forward successfully on that basis on national forest land, seeding 86,600 acres by the end of 1945 and 31,231 acres in 1946. Other agencies and private owners have also done much seeding on sagebrush lands, totalling approximately 350,000 acres in Utah and around 250,000 acres in Idaho by the end of 1946. This seeding has been done without an unusually large number of failures. Most of the failures that have occurred have resulted from the fact that operators did not observe all the recommended precautions.

Our information for reseeded on sagebrush lands is dependable on the whole, but there are a considerable number of specific problems not solved, or at least only partly solved. Among these problems requiring more knowledge are those dealing with new species and strains of species; what to do with lands of low productivity; how to lower the costs of large-scale operations; the need for more suitable machinery, especially for rough or stony land; how to clear land in rabbitbrush or greasewood; and how to prevent an invasion of grass stands by young sagebrush and rabbitbrush.

In the mountain-brush and aspen zone, the studies are comparatively new except for a few "pilot" plantings made in the middle and late 1930's and a few made several years before that. It is clearly established from older plantings that smooth brome and mountain brome do well and persist in this zone but not in the drier lower foothills and valleys. Orchardgrass, tall oatgrass, and timothy are also promising. Seed sown without seed covering under aspen in the fall will be effectively covered by falling leaves. It looks as if the same results will be obtained by leaves from maple, oak, and chokecherry which, however, are as yet indications rather than fully established facts. It is also known that the better soils and the precipitation are even more favorable than those at lower elevations.

How to remove mountain brush at a low cost is a definite problem. Burning has given some promising preliminary results. Machinery suited for sagebrush removal is most likely inadequate for oak, chokecherry, and maple brush. The need for reducing the costs of handling comparatively small areas of suitable land between rocky ridges is also a major problem. Nor is it as yet known whether steep slopes can justifiably be reseeded when costs and the risk of removing native cover are both considered. It is inevitable that for one to two years after brush removal flood and erosion hazards are high until the reseeded grasses become well established.

In the higher mountains investigational work is only begun, except for a very few early "pilot" plantings. Smooth brome is known to persist for many years when once a good stand is secured. Mountain brome also does well; orchardgrass, tall oatgrass, and timothy look promising, but are not as yet fully tested on a variety of sites. The growing season is short and many of the areas are small and rough, and have lost much of the topsoil. How to handle

eroded areas occupied by such weeds as tarweed, dandelion, wyethia, and penstemon remains largely to be investigated, although some fairly safe indications have shown up.

Raw clay subsoils are rather common in central Utah and how to handle them is far from solved. This is likewise true of raw gritty soils in northern Utah. Loose sandy soils of southern Utah present another problem as yet but partly solved. The loose granitic soils of central Idaho present an extremely difficult problem. For the last year particularly, emphasis has been placed on studies in the Boise area of granitic soils, but investigations have not as yet supplied a satisfactory solution. It is just possible that in the long run it may prove best to seed liberal acreages at lower elevations and protect steep upper slopes of the loose granitic watersheds by withdrawing most of the livestock to the lower reseeded ranges, where by a vigorous effort fairly adequate forage may be produced.

A program of studies is just now getting under way on salt-desert shrub ranges used for winter grazing.

Species and Strains

Over a period of years only a comparatively small number of species out of approximately 350 so far investigated have proved themselves to be suitable for use in reseeding in the Intermountain region. In the true sagebrush zone of the valleys and lower foothills, crested wheatgrass (Agropyron cristatum) is adapted throughout the area. On heavier soils containing some soil alkali western wheatgrass (Agropyron smithii) is adapted for seeding in a mixture with crested wheatgrass. Low germination and poor establishment of western wheatgrass prevent its being used alone. Crested wheatgrass does well up to about 7,500 feet elevation in central Utah and about 6,500 feet in central Idaho. In mountain brush and aspen zones or their elevational equivalents the reliably adapted species are smooth brome (Bromus inermis), orchardgrass (Dactylis glomerata), tall oatgrass (Arrhenatherum elatius), timothy (Phleum pratense), and mountain brome (Bromus carinatus). Recommendations based on these standard species have not been changed by any recent data. These are still basic species for action reseeding.

Two new things are developing, however, which are pointing to the likelihood of considerable modification in recommended species and strains for seeding after a few years. (1) Several species new with us introduced from Asia have been included during the last three or four years in species adaptability studies and look so promising they must be investigated thoroughly as quickly as it can be done. (2) Strains of a number of our standard species are found to differ so much from other strains of the same species that research directed toward obtaining and investigating the suitability of various strains should be intensified greatly in the immediate future years.

Tall wheatgrass (Agropyron elongatum), intermediate wheatgrass (A. intermedium), stiffhair wheatgrass (L. trichophorum), and Russian wildrye (Elymus junceus) have been in nearly all comparative studies for two years. The three wheatgrasses have the highly desirable quality of remaining green and therefore

palatable in July and sometimes in August. Since intermediate wheatgrass has outyielded crested wheatgrass in several preliminary comparisons in the valleys and foothills, and especially in the mountain brush zone, it appears as if it might somewhat increase forage production and materially lengthen the season of palatable forage. Crested wheatgrass has one well-known weakness-that of becoming woody and very unpalatable as soon as it begins to turn straw-colored with approaching maturity, which normally occurs at lower elevations about the last week of June. Russian wildrye produces in the mountain brush zone a high yield of forage that is several days ahead of native species in producing enough volume to be grazed effectively. In the lower zone it dries early, but does not become so hard and unpalatable as does crested wheatgrass.

The study of 15 species in plots 6 by 400 feet sown separately on Dusterberg is especially instructive as it includes a number of species markedly superior at 8,000 feet elevation to the standbys in the foothill and valleys. Crested wheatgrass averaged 1,350 pounds of air-dry forage per acre as compared with almost 3,000 for smooth brome, on 9 plots; on 2 plots each, 3,200 pounds for Agropyron intermedium (a promising new species); 3,000 for tall oatgrass; 3,125 for Agropyron repens; 3,125 for Bromus erectus; 2,600 for Agropyron elongatum (a promising new species); and 3,000 for Agropyron trichophorum (a promising new species, in one plot). These comparative yields were approximately corroborated in the Major Flat nursery. It takes many plantings and several years of study to determine with assurance the comparative value of species. It already seems clear, however, that a number of species are superior to crested wheatgrass in mountainous areas and that three new species are very promising. It is also clear that on good sites forage yields are likely to exceed greatly those obtained in the valleys and foothills. Yields of 3,000 pounds of air-dry forage are equivalent to more than 4 cow months per acre. This high forage production is the combined result of high precipitation (26 inches), deep fertile soil, adapted species, and proper methods of culture, including burning off the heavy brush.

Variations in height and yield of strains of slender, crested, and bluebunch wheatgrasses, and in smooth and mountain bromes are shown in table 1. Notable variations also occur in earliness and leafiness, but these are not yet well enough documented to put into a table.

Considerable effort is being put into obtaining for comparative study a group of species that may prove more suitable to the low-precipitation zone occupied by salt-desert shrub which comprises most of the winter sheep range in our region. Some of the desert shrubs will also be included in this phase of research as it develops.

Unfortunately the common legumes (they have all been studied) have not proved to be suitable for range reseeding. At present none of them is included in the recommended species for range reseeding. We have obtained a few new ones, principally from SCS nurseries, and are on the lookout for others.

Table 1. Average height in inches and yield of dry weight in pounds per acre of strains of indicated forage species for four or five years. Major Flat, Ephraim Canyon, Utah

Strain number	Height (inches)	Yield - dry wt. (Lbs. per acre)
<u>Slender wheatgrass (<i>Agropyron trachycaulum</i>) (1942-3-4-5-6)</u>		
43	35	3,855
38	32	3,009
30	26	2,423
29	28	2,112
15	19	1,374
<u>Crested wheatgrass (<i>Agropyron cristatum</i>) (1943-4-5-6)</u>		
25	30	4,453
24	27	3,887
23	26	2,791
21	26	2,691
<u>Mountain brome (<i>Bromus carinatus</i>) (1943-4-5-6)</u>		
46	32	4,969
41	35	3,660
36	30	2,340
23	26	1,474
29	32	1,309
<u>Smooth brome (<i>Bromus inermis</i>) (1943-4-5-6)</u>		
35	33	5,868
27	33	4,619
23	31	3,515
13	31	3,112
19	28	1,119
<u>Bluebunch wheatgrass (<i>Agropyron spicatum</i>) (1943-4-5-6)</u>		
3	33	6,676
26	29	5,404
17	32	3,522
16	29	1,269

Time of Seeding

Spring seeding, contrary to generally recommended practice of fall seeding, has been found successful near Paradise Valley, Nevada, and in the subalpine zone in Ephraim Canyon, Utah. Enough summer rainfall was received in these localities to let seedlings develop enough of a root system to become established. Spring and early summer seedings in Ephraim Canyon gave better stands in 4 out of 5 years, 1941-1945, than fall seeding. In 1942, a dry summer, fall seeding, however, was more than twice as good as spring, 14 percent as compared with 6 percent of established plants for the seeds sown. Late fall seeding gave better stands every year than early fall.

When spring and early summer seedings receive enough well-distributed precipitation, stands are better because winter killing losses are avoided. The general recommendation of fall seeding, however, is still correct for all the foothill and valley country in Utah and Idaho, and in the parts of Nevada that have dry summers.

Methods of Reducing Competition

Sagebrush--Reducing stands of sagebrush, mountain brush, and weeds before seeding has been found to be necessary in order to lessen the degree to which these plants compete with newly seeded grass.

At Paradise Valley, Nevada, for example, 21 forage species produced in the third year on a small plot basis, forage yields of 676, 1,148, and 2,141 pounds per acre when the competition with sagebrush was intense, reduced, and none respectively. Strips 3 yards wide cleared of sagebrush were seeded. Roots from border plants extended under ground across the strip and gave intense competition. Reduced competition was secured by trenching 12 inches deep along the plot borders, cutting off most but not all roots. All competition was removed by seeding in the interior of an acre completely cleared.

At Sublett, Idaho, large plantings conducted in cooperation with the Grazing Service, showed that railing, burning, and drilling produced 2,120 pounds of green forage per acre (air-dry is about 50 percent of green) in comparison with 738 pounds for railing twice and drilling; 529 pounds for broadcasting and railing twice; 281 pounds for broadcasting and railing once; and 50 pounds on the untreated native sagebrush range. One railing killed 35 percent of the sagebrush, double railing 53 percent, and railing followed by burning 92 percent.

A wheatland plow in proper adjustment and under favorable conditions may kill 85 or 90 percent of the brush but when improperly adjusted and on rough ground may kill only 70 or 75 percent. Some careless operations have removed only 50 to 60 percent. In comparison, railing except in old brittle brush, removed no more than 50 to 60 percent with two railings and only 30 to 40 percent with one. On ground too rough or rocky for either the wheatland plow or rail drags, the Dixie log (or pipe) harrow has been used to advantage but in most cases did not remove more than 30 to 50 percent of the sagebrush.

Burning has proved a better means of removing sagebrush on great stretches of sagebrush range throughout the region where the cover of brush, or brush and cheatgrass is heavy enough to carry the fire. In prescribed burning, precautions must be taken to control the fire. Our best results have been obtained when drilling was done directly on burned sagebrush land, without other seedbed preparation. Seeding done in the same season as the burning gave grass stands before occupation by cheatgrass or weeds occurred. Burning, was found also to leave most of the native perennial grasses little injured. These therefore were added to the stand of reseeded grasses. The cost of burning areas of 1,000 acres or larger was determined to be about 35 cents an acre, about one-fifth the cost of wheatland plowing. (Farmers' Bull. 1948)

Mountain brush--Although reseeded investigations in the mountain-brush, aspen, and subalpine zones are still new, valuable information has already begun to accumulate. The new effort has established clearly that several distinct and largely unsolved problems occur in the mountainous areas.

On Dusterberg Ridge in Ephraim at an elevation of 7,500 to 8,100 feet a heavy native cover of mixed snowberry, serviceberry, sagebrush, and a smaller amount of oakbrush was prepared for seeding and seeded in the fall of 1944. Herbaceous understory was very sparse, consisting mainly of a little slender wheatgrass, needlegrass, and penstemon. Slopes varied from 5 to 40 percent. The soil was a good, deep clay loam slightly eroded in the past.

The cover was removed from 45 acres by burning in late September, the seed broadcast and disked in because a drill was not immediately available; the wheatland plow was used on 50 acres and the seed broadcast ahead of the plow; on 15 acres seed was broadcast and disked; 5 acres under oakbrush and 15 acres under maple brush were broadcast without treatment; and 20 acres of sagebrush and snowberry were broadcast without treatment. The seeds consisted of a mixture of several adapted species sown at the rate of 10 to 15 pounds an acre depending on the size of seeds. On one side of the burn 15 species were sown alone except that 5 pounds per acre of smooth brome was sown on all plots.

Grasses on the burned area made much the most rapid growth and by August 15, 1946 had produced yields of air-dry forage of 1,500 to 3,900 pounds per acre, averaging on two transects of 20 plots each 2,176 and 2,285 pounds per acre. Since native range was producing only about 90 to 100 pounds of forage, the burned area produced in the second year after seeding more than 20 times as much forage per acre.

A good stand was developing in 1946 on the area treated with a wheatland plow and under maple where the fallen leaves served as a cover for the seeds. Another year will be required to give stands that are as well developed as on the burned-over area. Under oakbrush was a less certain stand and little was obtained from merely broadcasting seed, or from disked in native cover after seeding.

Tarweed--Much high-value watershed range has been overgrazed or mismanaged and somewhat eroded until many naturally splendid sites are occupied by almost pure stands of tarweed (Madia), dandelion (Taraxacum), povertyweed (Iva axillaris) or Wyethia, with little else in the cover. Several attempts at reseeding have been made on tarweed areas, the most common of deteriorated weed types on Utah forests. Fall plowing or cultivation followed by reseeding has generally returned a heavy stand of tarweed and not much grass. A careful study showed that this annual ripened seed early and cultivation after that promotes the growth of tarweed. The grass usually started but was smothered by the faster growing annual. Preliminary studies as to time of cultivation showed that destroying tarweed as early as the ground was dry enough to permit the use of machinery largely eliminated tarweed and gave good stands of grass. Other weeds present somewhat different problems but will likely yield to suitable variations in time or method of cultivation which need to be determined.

Cheatgrass--Reducing the competition from cheatgrass cover in order to reseed is not as simple as it might appear. Much of the land is steep and rough. Plowing in many cases has not been effective since considerable cheatgrass reappears the year after plowing and since seedbeds for reseeding on cheatgrass lands are loose and porous, and dry out excessively. Promising preliminary information has been obtained recently. Prolonged close grazing will largely prevent seed production thus providing a good seedbed for reseeded perennials. This lead is being followed up.

It has been found, also, that cheatgrass burned off in summer makes a poor growth the succeeding spring. Data on this point from southwestern Idaho are presented in table 2. Summer burning (June to September inclusive) while seeds are still attached to the plants reduced the number of plants the following spring by 85 to 98 percent.

Table 2. Number of cheatgrass plants per square foot in the spring of 1944, 1945, and 1946, on unburned plots and on plots burned at monthly intervals during the preceding year. (Near Boise, Idaho)

Date of burning	Number of plants per sq. ft. in spring of		
	1944	1945	1946
June 15	14	26	65
July 15	11	21	42
August 15	41	36	40
September 15	*	59	51
October 15	46	*	*
November 15	124	1,325	112
Not burned	299	1,090	423

* Plot not burned on this date

Reduction in numbers of cheatgrass plants is favorable to seeding and leaves a good seedbed. On the contrary, burning in November after the seeds had dropped gave nearly full stands of cheatgrass the next spring. Further studies may reveal burning cheatgrass to be an effective means of making essential reductions in competition for successful reseeding.

Machinery

Plow, tillage implements, and drills now available were developed for farm use. Certain of their parts break too easily when the machines are used on rough range land. Cooperative with the Equipment Laboratory, studies are under way to determine what is needed to correct these weaknesses. Types of drags for railing down brush are being given some attention to improve their effectiveness and to lessen the power required. More concerted study is needed on rails, if the importance of railing warrants it. At present it looks as if other methods of brush removal such as plowing and burning have greater promise. Prescribed burning has been well investigated for sagebrush and deserves much wider application than it has been given.

A stump-jump plow arrived from Australia too late to be given trial before winter set in. It will be tested for effectiveness on rocky ground and in land covered with coarse brush.

Airplane Seeding

During early October 1945, three areas of approximately 1,300 acres total of deteriorated aspen and oakbrush range in Ephraim Canyon, Utah were seeded by airplane. Falling leaves covered the seeds. Careful observations of flying time and difficulties of seed distribution in calm and slight winds, and costs of operation were recorded and studied. A detailed manuscript report on these phases was prepared and furnished to the Washington Office and western stations last June. The annual report of 1945 contained a summary statement of findings. In September 1946 an examination of resulting stands was made.

A meandering transect of plots was used to sample the three seeded areas designated as follows: (1) Maple Creek (aspen) 56 plots; (2) the "Hole" (aspen) 40 plots; and (3) Oakbrush (oakbrush) 60 plots. Grass seedlings were counted on each plot of 9.6 square feet. On 61 plots, no grass plants were found to be established; on other plots the count varied from less than 10 seedlings up to more than 60 per plot. The average numbers of established plots from reseeding were 0.89 per square foot in Maple Creek, 0.75 per square foot in the "Hole," and 0.74 per square foot in the Oakbrush area; including in the average the plots with no seedlings. It is possible that a considerable number of seedlings were missed in the count as they were small and as in many cases there was much litter on the ground.

The spring of 1946 had been at first unusually cold and then almost unprecedentedly dry. Many seeds were found throughout that had not germinated and which appeared to be still in good condition. It is expected that many more will germinate during 1947 and become established. Except for the

"misses" there are enough plants now to make a reasonably good stand. As judged by results obtained previously from hand broadcasting, these areas will as a whole produce a good stand of reseeded grass.

Oakbrush grows in open clumps with openings between. Plot counts of grass seedlings were made in various locations with reference to clumps of oakbrush. The number of grass seedlings per square foot were as follows: North side 1.34, south side 0.13, middle of clump 0.95, and in openings between clumps 0.25 plants.

A report from an administrative seeding on 16,000 acres on the Cow Creek burn (Boise Forest) shows mixed results. In 1945 about 500 acres on land of gentle slopes was drilled with excellent results, and another 700 acres drilled in the fall of 1946 from which reasonable success is expected. Another 2,000 acres were hand broadcast and where a good ash cover was present intermediate results were obtained. A mixture of bulbous bluegrass (Poa bulbosa), crested wheatgrass and smooth brome distributed by airplane gave a fairly uniform thin stand of bulbous bluegrass, and at intervals some crested wheatgrass, and a few scattered brome grass plants. Apparently, crested wheatgrass and smooth brome established themselves only on loose soil or where larger brush had burned and left enough ash to cover the seed. Pronounced success of reseeding from the airplane trial is questionable.

Grazing Reseeded Lands

Experimental grazing in 18 100-acre pastures at Benmore, Utah showed in the main the same over-all result as in 1945. Gains for cattle varied from 1.3 to 2.6 pounds and averaged 1.87 pounds per head a day in the pastures as compared with 1.70 pounds in a large unseeded sagebrush pasture. When calf gains were added to that of their mothers, the gains of all cattle over 6 months of age were 2.81 pounds daily for the pastures and 2.29 pounds daily for the unseeded sagebrush range, or daily gains that were 1.23 times as great in the seeded pastures. Spring grazing in the pastures required 2 acres per cow month with a utilization of 70.5 percent as compared with 14 acres per cow month on nearby sagebrush range, or seven times as much grazing capacity per acre for the seeded pastures.

The grazing capacity in 1946 was less than that in 1945 (1-1/2 acres per cow month) on account of a very cold early spring during which grass grew slowly. Precipitation in late spring was low and the ground had already begun to dry by the time weather warmed up enough to permit rapid growth. The ratio of 7 to 1 for forage production on seeded as against unseeded land was the same in both years. The relative meat gain in the seeded pasture is 8.6 to 1. Gains of cattle were observed to vary noticeably with the degree of forage utilization. Utilization of forage was higher than desirable owing to the short feed. Two pastures individually grazed to more than 75 percent produced only 1.3 and 1.5 pounds per day, showing the immediate effect of overutilization of the forage, in comparison with an average daily gain on all reseeded pastures of 1.87 pounds a head for cattle over 6 months of age. The average utilization of forage on all pastures was 70.5 percent. Calves, however, in the pastures gained essentially the same in the two heavily used pastures as in the others, apparently maintaining their growth at the expense of their mothers.

In a sheep grazing experiment on the Sorenson Field near Ephraim, Utah, crested wheatgrass produced 5.8 sheep months per acre in comparison with 2.9 sheep months per acre for rye, which was frozen back more severely than crested wheatgrass in May. The averages for 4 years (1943 to 1946) were equal, approximately 6-1/2 sheep months per acre for each. The rye, however, cost 12 cents per sheep month of forage and the crested wheatgrass 6 cents, as a 4-year average.

Forage Production and Costs on Some Large Areas

Data on nine areas handled by big-scale methods were gathered for 1946. These data together with one 1945 reading are given in table 3 with descriptive information to aid in interpreting the figures. The really great increases in yield are both highly pleasing and also reliable. Many other areas on which detailed data are not available are estimated to show as good forage production.

During 1946 the Regional Office and the Station have cooperated in seeding 480 acres north of Elko, Nevada, on a site designated as Dinner Station. This has permitted a study of costs and effectiveness of different large-scale methods of brush removal and seeding. Removal of a mixed stand of sagebrush and rabbitbrush from part of the area by wheatland plowing in the summer cost \$2.05 an acre. The plowed land stood for some weeks and was drilled in the fall as a separate operation at a cost of \$0.79 an acre. Another part of the area was plowed and seeded in the fall by broadcasting seed ahead of the plow with a remodeled bait spreader previously adapted for seeding and described by Robertson. The combined operation cost was \$2.36 an acre. Broadcasting requires more seed per acre to get good distribution than does drilling. Since crested wheatgrass seed in 1946 cost 37 cents a pound, about double the usual price, the total costs were relatively high--\$6.06 an acre for plowing and drilling separately 8.7 pounds of seed per acre and \$7.54 for broadcasting 12.7 pounds per acre. For the first time in several years the cost of the seed was more than the cost of performing the work on the ground.

From July 1 to December 31, 1946 the Region seeded 31,231 acres on the forests of Utah, Idaho, Nevada, and Wyoming. The average cost was \$6.42 an acre not including fencing or the purchase of new equipment. The seeds used were stockpile seeds and cost only about 18 cents a pound.

The area of 821 acres in Ruby Valley, Nevada, seeded in cooperation with the Region in the fall of 1944 is ready to be grazed in the spring of 1947. In fact it was grazed lightly (4.8 acres per cow month) in the fall of 1946.

Table 3. Grazing capacity of reseeded range areas compared with similar adjacent unseeded ranges in Utah, Idaho and Nevada

Area	Age	Precipitation	Elevation	Acres	Grazing capacity		
					Seeded	Unseeded	Ratio of seeded to unseeded
(yrs.) (inches) (feet) (Sheep number/A.)							
Utah							
Ephraim							
Sorenson Field	5	12	5,500	40	$\frac{1}{5}$	0.20	25
Private	5	13	5,700	80	$\frac{1}{5}$	0.30	15
Dusterberg Ridge	2	26	8,500	150	10	0.50	20
Cedar Valley ^{3/}	4	13	4,500	260	10	1.00	10
Lost Creek	5	9	7,500	500	4	0.33	12
Idaho							
Dubois	3	10	5,500	20	8	0.50	16
Raft River ^{2/}	3	12	4,500	400	5	0.10	50
Willow Creek	3	18	4,000	800	4	$\frac{4}{0.50}$	8
Nevada							
Ruby Valley	2	15	6,000	815	$\frac{4}{3}$	$\frac{4}{0.30}$	10
Ellison Creek	3	18	6,000	615	$\frac{4}{10}$	$\frac{4}{1.00}$	10

^{1/} Grazed at rate of 7 sheep months; thought to be too heavy

^{2/} Cooperative with Grazing Service

^{3/} 1945 data, year unusually favorable season; 1946 data not available

^{4/} Not grazed--conservatively estimated

This is an interesting and instructive area on which to determine forage production and the effects of grazing on its varied seeding treatments, as follows:

Sagebrush cover--seeded to crested wheatgrass

402 acres plowed 2" to 4" deep July and August, seeded October and November

176 acres broadcast and plowed (2-4") October and November (one operation)

55 acres broadcast and plowed (June 1945 one operation)

58 acres plowed (6-8" deep) July; drilled October

55 acres railed, burned June; drilled November

21 acres plowed twice, July and October; broadcast October with second plowing. Brush removal on first plowing was unsatisfactory

Sagebrush cover--seeded to mixture

4 acres plowed twice, July and October. Drilled October. Rye 33; Agcr 3; Brin 2; Arel 1; Agpa 1

4 acres plowed twice, July and October. Drilled October. Rye 100 pounds

5.8 acres plowed July, drilled October to small plots of 6 species (Elg1, Pone, Poam, Agin, Agsu, and Agsi)

4 acres broadcast and plowed, October, drilled (by mistake) June 1945

Rabbitbrush cover--seeded to mixture

28 acres plowed July, drilled October, Agcr, Agsm, and Brin (3:1:1)

9 acres plowed July, drilled October, Agcr, Brin (3:1)

Invasion of Reseeded Stands by Sagebrush and Rabbitbrush

One of the major problems in range reseeding is to avoid or prevent sagebrush or rabbitbrush, or both, from reoccupying seeded areas.

In plowing, many sagebrush plants are left alive unless great care is taken. These continue to compete with grass. Rabbitbrush roots are tougher than those of sagebrush, more plants are usually left with some roots unbroken. Moreover, rabbitbrush sprouts after burning which kills big sagebrush. Threestipped sagebrush (*Artemisia tripartita*) common in parts of eastern Idaho also sprouts after burning, although not so fully as does rabbitbrush. Treatment with rail drags and Dixie log (or pipe) harrows commonly leave 50 percent or more of brush plants alive, especially when there are many young ones that do not break off readily.

Thin stands of grass permits the ready establishment of young sagebrush and rabbitbrush in the openings. Such invasion is serious in occasional years when unusually good crops of brush seeds are produced. If removal by burning or plowing comes after seed maturity and the land is seeded to grass, the brush seedlings start at the same time as reseeded grass. This was especially troublesome in 1937 near Dubois, Idaho and in 1944 in Ephraim Canyon, Utah. Brush seed must blow in from adjacent areas or is carried in the hair or wool of animals that cross the plowed or burned area. Finally, severe grazing of grass stands, especially young stands weakens the grass and on loose soil uproots many plants. In such openings brush seedlings readily take hold. Heavy grazing also favors the development of young brush plants already present.

Remedies fall obviously into two classes: (1) prevention, and (2) eradication. Among the methods of preventing reoccupation of reseeded areas by brush is a good plowing job, by keeping plow alignment properly adjusted and keeping the disks sharp. Such attention may increase the removal percentage by 10 to 20 percent, and more in some cases. Burning is very effective in removing sagebrush but less so with rabbitbrush on account of its sprouting afterward.

Careful tillage, timely operations, and use of plenty of seed are important in getting good stands of reseeded grass as promptly as possible in order to prevent invasion of brush or suppress brush seedlings. Obviously, brush removal whether by fire or mechanical means, done before brush seeds are mature will reduce the chance for reinfestation. Control of grazing animals and reseeding in large blocks will lessen invasion of brush from surrounding lands, as well as make it easier to handle livestock during grazing. Allowing livestock to graze on reseeded ranges only after the stands are firmly established and to utilize them moderately is necessary in order to avoid thinning out stands or weakening them in such a degree as to allow invasion or to diminish the suppression of brush by a good grass stand. Severe grazing not only opens the grass stand, but encourages production of brush seeds which fall in openings in the grass stand.

Eradication of brush where it has already reoccupied reseeded areas is by no means simple but requires earnest attention. Maintaining the grass in a vigorous condition is the first requisite. Mowing brush has been suggested but preliminary trials have not been promising. Our sagebrush is too coarse. It also sprouts in some degree, and rabbitbrush sprouts almost fully. Burning off grass and sagebrush after it is thick enough to burn would apparently be successful as fires have been found to do little injury to crested wheatgrass and other commonly used species. On the other hand, burning might accentuate rabbitbrush trouble by encouraging sprouting.

A preliminary application of 2-4-D spray in July 1946 appeared in the fall as if it would weaken and perhaps kill many sagebrush and rabbitbrush plants. This needs a thorough study and it is proposed to start such a study in 1947. It will be necessary to study not only effectiveness but also costs to make sure it will be cheaper to spray than to replant reseeded areas.

Study of Site Rating Begun

The first phases of work on a study of site rating were begun in 1946. Dr. Joseph H. Robertson has been assigned to this subproject and as a beginning, has made a study of available literature, developed a preliminary study plan, and put out a series of plots. The immediate aim is to develop the principles on which a comprehensive study will need to be organized and prosecuted.

Areas have been sought out on a series of sites where there is a full stand of seeded grass. On these areas plots were established. This will give the potential yield of sites in a series of conditions which vary in precipitation, exposure, depth, texture, parent material, organic matter, and water-holding capacity of the soil, and in original vegetation. When yields are obtained and correlated with the various site factors, indications will be

obtained as to which factors are most closely correlated with productivity of the series of sites, varying from low to high potential productivity. A similar study will be conducted so far as possible on areas being broken out of brush for reseeding. This phase, however, is complicated by the likelihood of only part of a stand being obtained on the plot chosen, thus making it difficult to assign the true productivity value to the site. This phase is therefore likely to make slower progress at first than on sites where the full stands are available for a beginning of the study.

It is hoped that it may be possible to divide sites into from three to five productivity classes which will indicate what may be expected in forage production on a given kind of site. It is also hoped that some few general principles may be found that will make a fairly simple procedure out of site rating. If the principles prove general enough they might permit the rating of sites in the mountain brush, the alpine, and sagebrush zones on the same factors. Possibly more than one set of factors may have to be used for rating sites in unlike ecological environments.

New Work and Personnel Changes in 1946

The study of site factors previously conducted as part of the general program of reseeding research began to be emphasized in 1946. An attempt is being made to develop the principles on which the rating and classification of sites might be undertaken. Effort on the prosecution of reseeding studies is being more and more concentrated in the mountain brush and subalpine zones. For the first time studies on the desert winter ranges (salt-desert shrub type) are being initiated as substantial part of the program of research. Hitherto, a few "pilot" plantings constituted all that had been done.

In order to strengthen the study and to get under way the new work just indicated the following additions or changes in personnel assignment were made during 1946: Joseph H. Robertson was moved from Paradise Valley, Nevada to Ogden to take charge of studies in site rating and classification. His previous position in charge of reseeding studies in Nevada was filled by R. M. Hurd who returned to the station after 5 years in the U. S. Navy in the Pacific. Two new men were added to the reseeding research personnel and placed in previously vacant positions. John M. Fenley (P-2) was assigned to reseeding studies in Utah and Neil C. Frischknecht (P-1) to desert reseeding studies at the Benmore grazing studies of reseeded crested wheatgrass range. Both men are quartered at Ephraim, Utah. Clark Holscher is assuming on-the-ground responsibility for supervising the prosecution of reseeding studies in southeastern Idaho as part of the work at the upper Snake River research center. Hull will concentrate on studies in western Idaho, where work on granitic soils need strengthening.

Plans for 1947

During 1947 it is planned to prosecute as vigorously as possible (a) the field investigations needed to fill in gaps and to provide progress in information for the different vegetation zones, and (b) preparation of manuscripts on such study data as are ready or can be made ready for publication.

A - Field Investigations

Sagebrush zone. Although a body of information great enough to warrant an "action" program has been accumulated for the sagebrush vegetation zone, a number of studies are yet needed to fill in critical gaps in our knowledge and to facilitate action programs.

1. To take data on a number of old studies and prepare findings for publication. Some of these studies will be closed and others left dormant to show duration of stands.
2. To investigate vigorously the value of promising new species and strains of species.
3. To gather comparative cost data of major methods of removing competition and of reseeding when applied to large-scale planting.
4. To determine, if possible, how to control stands of sagebrush and rabbit-brush that have occupied reseeded range lands.
5. To continue the study of how to get reseeded stands on tracts occupied by cheatgrass.
6. To continue Benmore grazing studies with such revisions as are required to improve the statistical design.

Mountain brush and subalpine zones. Since investigations in the mountainous zones are only well begun, it is planned to continue efforts there, giving special attention, as follows:

1. To enlarge studies on removal of competition from mountain brush, tarweed, dandelion, and other weeds.
2. To subject both old and new species and strains that are promising to a thorough study of their suitability to principal conditions in mountainous zones.
3. To take field data on the airplane seedings made in the fall of 1945, analyze the data and prepare a report.

Boise granitic soils. To emphasize studies on especially difficult soil types such as the loose granitic soils on the Boise area, heavy clays of central Utah, and the sandy areas of southern Utah.

Salt-desert shrub zone. It is planned to get under way on the salt-desert shrub winter range lands, a program for studying species suitability, methods of removing competition and seeding, and site adaptation. A beginning in this low-precipitation zone was made in 1946.

B - Publications

Major contributions were made in 1946 toward two range management publications and more is required to complete them in 1947. In 1946 several reseeding manuscripts were made ready or nearly ready for publication. These and additional ones which will be prepared in 1947 are listed below:

Competition between sagebrush and grass - Ecology - Hull
Reseeding range lands - mountain states - 1948 Yearbook - Hull
Season, depth, and date of seeding in Idaho - Journal American Society of Agronomy - Hull and Taylor
Cheatgrass: a challenge to range research - Journal of Forestry - Hull and Pechanec
Range reseeding - 1948 Yearbook - Plummer, et.al.
Forage species and strains - Journal American Society of Agronomy - Plummer
Range reseeding in Utah - Stockman's Review - Plummer
Season, date, and depth of seeding in Utah - Journal American Society of Agronomy - Plummer, Fenley
Treatment of seeds of ricegrass - Journal American Society of Agronomy - Plummer, Frischknecht
Responses of range grasses to competition - Ecology - Robertson
Season, date, and depth of seeding in Nevada - Research Paper - Robertson
Increasing range forage by reseeding - National Wool Grower - Stewart
Mountain waters: our heritage and obligation - Improvement Era - Stewart
Pasture for mountain states - 1948 Yearbook - Stewart
Reseeding Intermountain range lands - complete first draft during 1947 - Farmers' Bulletin - Members of Reseeding staff
Miscellaneous short articles for popular publications - Members of Reseeding staff

FLOOD CONTROL SURVEYS

Department of Agriculture flood control activities, suspended during the war, were resumed in 1946. Responsibility was allocated to the Forest Service and Soil Conservation Service on a watershed basis. Within the Forest Service, activities are centered at the California, Intermountain, Northeastern, and Southern Forest and Range Experiment Stations. Major watersheds on which flood control surveys will be conducted by the Intermountain Station include: all areas within the Great Basin; the Snake River above Lewiston; headwaters of the Missouri and Yellowstone Rivers; the upper Colorado River; and certain headwater areas of the lower Colorado, Rio Grande, Arkansas and Platte watersheds. In addition to the primary responsibility of the Forest Service for examinations and surveys on the above described areas, assistance will also be given to the Soil Conservation Service on watersheds for which that agency has primary responsibility. Contact is maintained with all flood control activities of other federal and local groups.

One of the first steps in reactivating the work at the Intermountain Station was that of recruiting personnel. Recruitment was started in the second quarter of the year and continued for several months. Most of the present staff reported for duty during July and August. At the close of the year a staff of 13 men was assigned to the project. Only six of the men had previous flood control survey experience. This lack of experience plus post-war revisions in Departmental policies and procedures made it necessary for the staff to devote considerable time to orientation in the program and investigation of survey work previously conducted within the assigned territory.

In resuming flood control survey work by the Department it was decided that the work programs of both the Forest Service and the SCS would first be directed to the revision of those pre-war reports which had not received Departmental approval and to the completion of surveys which were under way when the earlier work was interrupted by the war.

Accomplishments in 1946

Revision of Sevier Lake Watershed Report

During 1940 and 1941 a survey of the Sevier Lake watershed was made jointly by the Forest Service, Soil Conservation Service, and Bureau of Agricultural Economics. This report was never approved and retrenchment of activities prevented its immediate revision. Inasmuch as six years had passed since the original investigations were made and since significant changes had taken place on the watershed during that period, additional field study was necessary. Major work centered on analysis of changes in livestock range use and big game populations; variations in plant cover and erosion; changes in economic standards; accumulation of recent rainfall, storm, and stream flow data; and consideration of recent floods.

Productive work on the revision was delayed by a special, detailed study of the flood which occurred on Pleasant Creek on July 24 causing damages in excess of \$100,000. Representatives of the damaged community and personnel of Forest Service Region 4 requested that the causes of the flood be investigated, damages determined, and preventive measures recommended. Since the flood was of major consequence on one of the tributaries of the Sevier which had been sampled previously, the flood control staff made the study. A memorandum report covering the findings has been prepared. These findings will also be incorporated in the report for the Sevier Lake watershed.

At the close of the year all basic data essential to the revision of the Sevier report had been assembled and analyzed. Proposed program measures were developed and evaluated. Appendices were near completion and the report outline was prepared.

The Pleasant Creek Flood

On July 24, 1946, Mt. Pleasant was deluged with a flow of mud, rocks, and water from Pleasant Creek. Damages from the flow in and adjacent to the town were appraised at \$106,000. Debris was 4 feet deep in parts of town. Mud invaded homes and stores, ruining furniture, foodstuffs, merchandise, and interior decorations. Rocks and mud overflowed onto lawns, gardens, and agricultural lands, damaging crops and soil productivity.

In the absence of recorded measurements, the storm which caused this flood was estimated from field analysis to fall within the range of the 2.5-inch cloudburst type having a 50-year frequency. Rainfall of high intensity fell for about 40 minutes on the upper portion of the watershed and was largely concentrated on 5,176 acres or 46 percent of the 11,360 acres in the watershed above the mouth of the canyon. No rainfall occurred in town and only a trace fell at the canyon mouth.

According to testimony of lay observers, twenty minutes after the rainfall ceased, the flood wave was seen at the mouth of the canyon at a stage in excess of any known previous flood on Pleasant Creek. A short time later the rock and mud flows struck town; it remained at a high stage for an hour and was completely subsided two hours later. At the canyon mouth, the flood was first observed as a wave of fairly clear water which rapidly changed to the mud flow type of flood as run-off picked up soil in the storm area, gained momentum in the streams, and ripped additional debris and boulders from the channels. The force of the flow was such that boulders up to 10 feet in diameter were moved and stream banks and bottoms were gouged out. Eighty acre feet of large boulders and mud were deposited in two debris basins above town whereas an additional 100 acre feet were spread out in town and on the adjoining farm lands. The mud flow in town probably contained 25 to 60 percent sediment by volume.

The run-off which produced the flood originated largely on only 1,682 acres of the area subjected to intense rainfall. This small area generally occupies southern slopes in excess of 60 percent. Heavy grazing over a period of years has reduced the vegetation to such a low density that it offers inadequate site protection and widespread erosion has created unfavorable soil conditions. Because of the present low infiltration rates of the areas, the intense rainfall could not be absorbed and therefore run-off flowed rapidly over the surface into the drainage ways.

Revision of the Boise River Watershed Report

A joint survey of the Boise River watershed was conducted by the Forest Service, Soil Conservation Service, and Bureau of Agricultural Economics in 1938 and 1939 and a report prepared in 1940. This report did not receive Departmental approval and it was revised in 1943 but again approval was not obtained. No further work was undertaken until 1946. Since the original field survey, the Bureau of Reclamation obtained approval for the construction of the Anderson Ranch Dam and the Corps of Engineers for the Lucky Peak Dam. When both of these dams are completed there will be a material reduction in the flood control benefits claimed for treatment of watershed lands as recommended in the original USDA report.

Other factors which contributed to the need for a revision were the occurrence in 1943 of the largest flood since 1897, changes in range use, revegetation work of the Forest Service, and economic changes. As a result of a conference in October with the Corps of Engineers in Portland, a review of the Bureau of Reclamation report on Anderson Ranch Dam, and consultation with Forest Service personnel from the Washington office, it was concluded that a USDA watershed flood control program probably could be justified.

Although originally scheduled for completion in 1946, work was delayed in favor of the Sevier project in view of the complications on the Boise as mentioned above. However, all previous reports and related file data on the Boise River have now been studied and plans are under way for the actual field work.

Revision of Fountain River and Cherry Creek Watershed Reports

These two watersheds on the eastern slopes of the Rocky Mountains in Colorado were surveyed and reported upon in 1939 and 1941. Departmental approvals were not obtained and required changes were not completed. Although originally surveyed under the leadership of the Soil Conservation Service, the Forest Service was assigned major responsibility for the post-war revisions.

Both watersheds contain substantial amounts of cultivated land. Therefore considerable assistance from the Soil Conservation Service will be required to effect the necessary revision work. Several conferences were held with that agency regarding plans and assistance. Representatives of the Forest Service regional office at Denver and the Experiment Station at Fort Collins also were consulted concerning the original surveys, recent changes in watershed conditions, and other factors pertinent to the revisions.

The Cherry Creek revision will be affected materially by a Corps of Engineers flood control dam authorized in 1941 for the protection of the city of Denver near the mouth of the stream. A large portion of the benefits claimed in the first USDA report consisted of reduction in damages to Denver. The Corps of Engineers project greatly reduces the justification in the original USDA report and seriously affects the prospects of redesigning a satisfactory watershed flood control program that can meet the cost-benefit ratio requirement.

Survey of Watersheds Draining into the Great Salt Lake

A preliminary examination report on the Wasatch Front portion of this area was completed in 1941. A survey work outline was prepared and survey field work was begun late in 1941 but little progress was made because of the war.

Resumption of the detailed survey was authorized in 1946. A decision was reached to break the watershed into two or more parts and to report upon each part separately. During the year file material on previous work was reviewed and sources and adequacy of additional data were investigated. It was decided finally that the specific area selected for survey would cover the frontal streams from Wellsville on the north to Nephi on the south.

Cooperation with the Soil Conservation Service

Departmental policy and over-all procedure provide for close working relations between the flood control staffs of the Forest Service and the Soil Conservation Service. Although assigned individual responsibility for various watersheds, it was anticipated that technical assistance would be interchanged both for field surveys and the preparation of reports. In this connection, the Soil Conservation Service regional office at Portland was contacted and preliminary plans were formulated for cooperative work on the Boise River survey. Several conferences have been held with the Soil Conservation Service at Albuquerque relative to Forest Service participation in the surveys of Queen Creek, upper Gila River, and lower Gila River watersheds in Arizona and the Rio Puerco, Rio Chama, Pecos, and Rio Grande River watersheds in New Mexico. Discussions also covered Soil Conservation Service contributions to surveys of Sevier Lake, Cherry Creek, and Fountain River watersheds. Survey work outlines were interchanged and reviewed. Inter-agency assignments included the detail of Soil Conservation Service personnel totalling one man-month to the Sevier revision work and detail of Forest Service personnel for 3-1/2 man-months for work on Queen Creek and Rio Puerco watersheds.

Miscellaneous Activities

Policies now in effect provide for cooperation with field offices of other agencies involved in flood control and related problems. In 1946 activities in this direction included: (1) joint economic survey of damages caused by the July 24 flood on Pleasant Creek in cooperation with the Corps of Engineers; (2) review and comment on the Bureau of Reclamation report on the Virgin River covering certain irrigation projects; (3) review of the Columbia River Basin Committee paper on "The Pacific Northwest"; (4) participation in a meeting

at Billings for purpose of discussing interagency flood control and related programs for the Yellowstone River; (5) consultation with Corps of Engineers, Sacramento District, on the general aspects of flood problems in Utah, and (6) participation in meeting at Albuquerque, New Mexico attended by all state and federal agencies interested in the Rio Grande River watershed.

In addition to the Mt. Pleasant flood, three local floods which occurred in the late summer and early fall were investigated and data were incorporated in the file for later reference. These included floods in Meadow Valley Wash near Caliente, Nevada; Cedar Valley near Fairfield, Utah; and a local drainage near Deweyville, Utah.

Plans for 1947

Completion of Sevier Lake Watershed Report

During 1947, first priority will be given to the completion of the Sevier Lake report. The report will be prepared in preliminary draft form about March 15. After review by local Forest Service personnel it will be submitted to the field offices of the Soil Conservation Service and Bureau of Reclamation for comments. It will also be discussed with the Corps of Engineers.

Revisions of Other Survey Reports

Plans have been formulated and assignments have been made so that work may proceed concurrently on the three revision projects under way (Boise River, Cherry Creek, and Fountain River). Work outlines for these three watersheds will be prepared early in 1947. During the summer field season it is planned to gather all essential field information so that the preparation of reports may begin in the late summer. The reports should be completed by the end of the year.

A survey work outline for the Wasatch Front watershed will be prepared at an early date and as much field work as possible will be undertaken during the coming summer season. It is anticipated that the survey and report will not be completed until early 1948.

Miscellaneous Activity

It is expected that considerable effort will be expended on such other activities as investigating and reporting on local storms and floods. Likewise conferences, meetings, and hearings with other flood control and related interested agencies will demand considerable attention as part of the over-all effort to correlate all flood control and land use projects.

RANGE ECONOMICS

Range economics is that branch of economics concerned with the management and use of the western range and associated resources. These associated resources are the cultivated lands and range livestock included in the operating units which make use of the range. Range economics research at the Intermountain Station is concerned primarily with the economic evaluation of the various management alternatives available in the use of national forest ranges. These alternatives are given economic interpretation to determine which will yield the maximum, long-time benefits to dependent individuals and communities.

The importance of the range livestock industry in this region--the principal industry with which range economics has usually been concerned--is indicated by the fact that about one-third of the agricultural income is produced by beef cattle and sheep. The total agricultural income in 1945 amounted to three and one-quarter million dollars. A large proportion of this agricultural income was derived from irrigated farms whose well-being is directly influenced by use of the range. From the standpoint of area involved the range livestock industry is of tremendous importance. Of the 178 million acres in this region over 90 percent are grazed by livestock. Public policies with respect to range land are of great import to the range livestock industry since three-fourths of the land is publicly owned. These public range policies not only determine the use of much of the private land but also even help determine its value. Thus it can be seen that public policies with respect to national forest range use must be developed on sound knowledge. The promotion of this knowledge is the duty of range economics research.

A Brief Review of Past Work

The Range Economics project at the Intermountain Station was instituted in 1938. At that time a major problem confronting national forest management was the determination of the economic consequences of the management alternatives which could be followed in the conservation and use of the range. To determine and evaluate these adjustments studies were undertaken in two radically different areas.

The Northeastern Nevada Cooperative Study analyzed an area of large, specialized cattle and sheep ranches. The results of this work showed the extreme interdependence of public and private range and croplands. Ranches which lost all or part of their public grazing privileges had to make drastic reductions in the number of livestock operated and in many cases serious financial difficulties were encountered. This was due to the high cost of operating on private land--in which the value of low-cost public range had been capitalized. Shifts to production of cash crops, dairy production, and other adjustments were not available to operating units in this area. The most important cause of financial problems in this area was the reduction in livestock numbers operated due to reductions in the carrying capacity of the entire range resource.

The central Utah economic study analyzed a national forest area of many small farm and ranch livestock enterprises. About one-third of the grazing on public lands was by cattle from small farm cattle enterprises. Many of the small sheep permits were run in "co-op" bands which never saw the farm land. From a farm management standpoint these small range livestock enterprises were too small. Furthermore, they contributed only a minor portion, around 15 percent, of the total probable gross farm income. In the cash crop and dairying localities many of these small permittees could successfully shift their operations to dairying or cash crops and so eliminate use of public range. These small cattle and sheep enterprises did not properly utilize the farm labor supply. On the other hand some of the extremely large enterprises could also adjust their operations so as to operate successfully without the use of national forest range. Most of these large range operations had the major portion of their summer range on private land. Both of these economic studies indicate the necessity of analyzing individual farms and ranches when reductions must be made for protection of national forest grazing.

The question of the land charges borne by privately owned lands was analyzed. This analysis was made of ranches operating entirely on private land and developed the land charge per animal month on the various types of land. These land costs showed that in many instances the land charge per a.u.m. on hay meadows (both hay and hayland aftermath) was lower than on private range. Private range costs were considerably above those on public range.

Trends in the amount of public land grazing, distribution of grazing use, and season of use were analyzed and graphically presented for the education and use of land managers and other interested individuals and agencies. Studies of miscellaneous administrative problems have been made of such questions as trucking versus trailing of lambs to market. This study showed the benefits of trucking over trailing of lambs where long trail movements were involved. When the United States became involved in the war, all efforts were shifted to the food production problems of the region and the development of programs to encourage production of the desired kinds and amounts of agricultural products.

From June 1943 until October 1946 the project was inactive due to loss of personnel. In October a problem analysis was begun as the basis for the future work of the project. It soon became apparent that changing economic conditions had altered the importance of former problems and also created several very important ones. These major problems are discussed in the next section.

In response to the controversial question of the trend in numbers of range livestock, a study was made during the latter part of 1946 of several typical range areas in the region. The selected areas were ones where the range livestock population made a maximum use of range and a minimum use of harvested forage. The results showed that: (1) range livestock numbers in these areas had steadily declined from 1920 to 1945, (2) the recent increase in beef cattle numbers had not offset the large decline in sheep numbers, (3) permitted numbers on the national forests in these areas had declined in approximately the same degree as had the total range livestock population,

(4) only general conclusions can be drawn from data on livestock numbers for small areas due to the error in available data.

The Major Problems Facing Range Economics

The paramount problem facing national forest administration in the Intermountain region is the reduction of livestock numbers to meet the grazing capacity of national forest range-watersheds. One hundred and fifty-five cattle allotments and 292 sheep allotments require varying degrees of decreased use to protect the resource values involved. Some of these reductions run over 50 percent. The methods by which grazing use can be brought down to the proper level with a minimum of economic and social loss to dependent operators is the major problem facing range economics research.

The most feasible method of accomplishing this adjustment is the production of more range forage through artificial reseeding of depleted range or abandoned cropland. Estimates of the acreage of depleted range and abandoned cropland in the region run as high as twelve million acres so that abundant opportunities for reseeding exist provided such a practice is economically feasible to the stockman. The economics of reseeding is the major problem for range economics research. This problem must be approached from the standpoint of its influence on livestock production and ranch income. Simply determining the cost of seed and seeding and the increase in animal unit months of forage is not sufficient. In the year-round operation development of spring-fall range may produce substantially larger calf or lamb crops, lower death losses, and reduce the use of supplemental feed so that a relatively high cost may be warranted by reseeding. Where reseeded range means the difference between an efficient and inefficient sized operating unit its value is greatly enhanced over the mere value of an animal month of grazing.

In order to fully comprehend the problem of deteriorated range-watersheds it is necessary to determine the use values involved, including not only the forage use but also the watershed and other uses. Almost all national forest lands perform two or more functions or perhaps we should say have two or more uses. This is the concept of multiple use. Each use has a value and the problem is to determine what these values are. On many of our range-watersheds we have several values affected by improper use of the resource. For example, overgrazing may be adversely influencing the irrigation water supply function of the range-watershed as well as reducing the grazing capacity. We need to determine the economic value of each use so as to give priority to the use or uses with the highest economic value. Heretofore we have known only the value of grazing use, and even this value has not been clearly defined. Indications are that the value of the watershed function may far outstrip the value of grazing. It seems logical to assume that we must utilize national forest lands on the basis of the most valuable uses. What are these values for water, grazing, timber, and recreation? Valuation does not necessarily have to be in terms of dollars and cents, however, some quantitative measure or "yardstick" is necessary so as to yield comparable results. Resource use evaluation is especially timely because of the current "Know Your Watershed Program," and is a major problem for range economics research.

With the question of resource evaluation solved, the problem still exists of how to bring about the necessary adjustments to maintain and restore the resource use with the most value. These adjustments will probably be those required to maintain and restore the watershed resource such as proper stocking, proper seasonal use, and reseedling of depleted range-watersheds. If it were possible to properly graze national forest range-watersheds and still maintain incomes from range livestock grazing on these lands the problem would be relatively simple. However, we have little, if any, information to indicate that ranch incomes will be maintained when proper stocking is brought about. (It may be possible on certain farms to maintain the income by shifting from range livestock production to other types of production such as dairying, cash crops, etc. However, this will generally be true only of the more productive lands close to marketing channels.) The reduction in livestock numbers generally must be too drastic. In some cases complete elimination of grazing is necessary.

Several other economic problems are of major importance to range economics research such as the distribution of grazing preferences among the various sizes and types of farm and ranch operations, land charges (including capital values, range land taxation and grazing fees) and the classification of national forest lands. However, because of the greater importance of the two major problems--the economics of reseedling and resource use valuation--these lesser problems do not merit discussion at the present time.

Plans for the Future

In the immediate future it is planned to institute an economic analysis of artificial reseedling and the use of artificially reseeded range lands. This study will be broken down into three stages or steps. The first stage will study the various costs involved in reseedling the different kinds of land in the different areas of the Intermountain region. The second stage will analyze the influence of reseeded range on ranch organization and management. The third and final step will be the analysis of the benefits of reseeded range expressed in terms of ranch income. The complete study will provide a thorough knowledge of the economics of this practice which appears to be the best solution to the many range economic problems confronting public land managers in this region.

February 3, 1947

BIG GAME-LIVESTOCK RANGE IN UTAH

1. Field division: Range research
2. Work project: Grazing management
3. Line project: Big game-livestock range
4. Purpose: To gather facts and develop principles and concepts which will form the basis for management of range lands for production of big game and livestock and for conservation of other values.
5. Review of past work: Overbrowsing has been recognized on many deer and elk ranges of the region. Preliminary deer range studies on forage value and preferences, carrying capacity, and census methods were made within a fenced deer pasture near Fillmore, Utah, in cooperation with State agencies in 1939-42. This work ended when fire destroyed the fences in 1942. Administrative studies are under way on forage preferences, game populations, and range trends. Enclosures have been constructed for further investigation.
6. Accomplishments during past year: A cooperative organization was formed to carry out a coordinated research program and a memorandum of understanding was formulated with the Utah State Fish and Game Commission, Utah State Agricultural College, U. S. Fish and Wildlife Service, and the Bureau of Land Management. Problem analysis is well under way. Game range conditions in Utah have been investigated and tentative areas have been selected for exploratory studies. Maps are being prepared showing game and livestock numbers and problem areas. A bibliography of past work and pertinent literature has been prepared and abstracted.
7. Plans for next year: Complete problem analysis and formulate plans for the research program. Conduct exploratory studies in big game and livestock food habit relationships and determine suitable methods of studying forage utilization under various combinations of game and livestock use. Collect information for a cross section picture of big game-livestock range conditions and problems in Utah.
8. Date of completion: Indefinite
9. Assignment: Odell Julander and Justin G. Smith

February 3, 1947

FLOOD CONTROL SURVEY /ND REPORT (REVISION)
SEVIER LAKE WATERSHED

1. Field division: Flood control surveys
2. Work project: Flood control surveys
3. Line project: Detailed survey of approved watersheds for preparing action program.
4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, costs, and benefits of measures needed to be applied for flood control and prevention of accelerated soil erosion on the Sevier Lake Watershed, Utah, and to prepare a report of these findings.
5. Review of past work: In 1940 and 1941 a survey of this watershed was completed and a report submitted. Departmental approval of the report was not obtained at that time. Before the required revisions could be made the war caused a cessation of flood control activities. Following resumption of this work in 1946 changes in policy and procedure, together with changed conditions on the watersheds and new data, made it necessary to completely revise the report in order to bring it up to date.
6. Accomplishments during past year: Field work completed on revision of past damages, factors contributing to flood hazard, and requirements of remedial program. Data relating to years 1941-1946 were secured and analyzed. Analyses of hydrologic, economic, and land use data were revised. Entire report revised to 1946 monetary base. Writing of final report and appendices was begun. Results of study and proposed recommendations presented to Region 4 and preliminary clearance obtained. Field assistance obtained from SCS on downstream engineering and remedial program on private land outside national forests.
7. Plans for next year: Completion of report. Obtain field clearance of report from other agencies and incidental work relative to its final acceptance and publication.
8. Date of completion: 1947
9. Assignment: Flood control personnel, principally Lobenstein, Taylor, Baudendistel, Rosa, Adams.

February 3, 1947

FLOOD CONTROL SURVEY AND REPORT
WASATCH FRONT

1. Field division: Flood control surveys
2. Work project: Flood control surveys
3. Line project: Detailed survey of an approved watershed for action program.
4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, cost and benefits of measures to be applied for flood control, and the prevention of accelerated soil erosion on the Wasatch Front, Utah, watershed lands, and to prepare a report of these findings.
5. Review of past work: The preliminary report on the Wasatch Front tributaries was completed and submitted to the Flood Control Advisory Committee on March 15, 1941. The committee approved the field recommendation and allotted \$5,000 for initial planning phases including the preparation of a survey work outline describing the major jobs, sequence of work, and the budgetary requirements for conducting the survey. This report was submitted to Washington on January 28, 1942. The field work was begun in the late fall of 1941 but due to our country entering the war at that time all flood control activities were stopped.
6. Accomplishments during past year: The work outline for the Wasatch Front Watershed survey was reviewed by the flood control survey personnel assigned to this project and plans started for beginning the survey, with emphasis placed upon that part of the watershed which consists mostly of frontal streams.
7. Plans for next year: During the next year it is planned to complete all field work necessary, compile this information, and begin preparation of the report.
8. Date of completion: Spring of 1948.
9. Assignment: Flood control survey personnel. J. D. Hansen, project leader.

February 3, 1947

FLOOD CONTROL SURVEY AND REPORT (REVISION)
BOISE RIVER WATERSHED

1. Field division: Flood control surveys
2. Work project: Flood control surveys
3. Line project: Watershed surveys: Detailed survey of approved watersheds for preparing work program.
4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, cost, and benefits of measures needed to be applied for flood control and prevention of accelerated soil erosion on the watershed lands of the Boise River, Idaho, drainage basin, and to prepare a report of these findings.
5. Review of past work: Work on the survey was initiated in 1938. Field work was completed and a report prepared and submitted to Washington in 1940. This report was not approved and a revision of the report was completed in 1943. Again Departmental clearance of the report was not obtained, partly on account of the effect of the war on flood control activities. Changes in Departmental policy and procedures together with recent developments on the watershed nullified much of the original work and made further revision and some additional field work necessary.
6. Accomplishments during the past year: The original report and appendices and the 1943 revision have been carefully studied by FCS personnel. The recently approved program by the Corps of Engineers for a flood control reservoir at Lucky Peak has been studied with particular respect to the effect of this program upon the Department of Agriculture flood control program. Personnel of the Corps of Engineers were contacted and the interrelation of the two programs discussed. New flood and damage data were studied. The relation of sediment discharge data on sample areas was worked out from data not previously analyzed.
7. Plans for next year: It will be necessary to conduct a sediment reconnaissance survey, obtain new damage data from the Portland office of Corps of Engineers--probably supplemented by a brief field study--and to make a reconnaissance survey of watershed conditions. All data pertaining to damages, program costs and benefits will need to be adjusted to a 1947 level. The report and appendices will be revised and the report submitted to interested agencies for field clearance. Some incidental work relative to final acceptance and publication is anticipated.
8. Date of completion: 1947
9. Assignment: Flood control personnel. Marvin Rosa, project leader.

February 3, 1947

FLOOD CONTROL SURVEY AND REPORT (REVISION)
CHERRY CREEK WATERSHED

1. Field division: Flood control surveys
2. Work project: Flood control surveys
3. Line project: Detailed survey of approved watersheds for preparing action program.
4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, cost, and benefits of measures needed to be applied for flood control and prevention of accelerated soil erosion on the watershed lands of the Cherry Creek drainage basin, and to prepare a report of these findings.
5. Review of past work: A watershed survey was conducted under the leadership of the SCS and a flood control report prepared and submitted in 1941. This report was not approved at the Departmental level but suspension of flood control survey activities during the war prevented the required revision.
6. Accomplishments during the past year: Resumption of flood control survey work in 1946 reactivated this survey. Agreement was reached in Washington by the FS and SCS that the report would be revised and brought up to date under supervision of FS. All available pertinent file material, recorded data, maps and tracings were obtained from SCS and reviewed. The SCS at Albuquerque was contacted concerning over-all approach to problem, and preliminary plans were worked out with that agency for the detail of SCS personnel. The Corps of Engineers flood control program which was authorized in 1946 was analyzed with respect to possible effect upon USDA program. A search for and study of new hydrologic data was started. Proposed program discussed with the Rocky Mountain Experiment Station and Region 2.
7. Plans for next year: Carry out necessary field work including assistance from SCS. Complete report and obtain field clearance from interested agencies.
8. Date of completion: 1947
9. Assignment of personnel: Flood control personnel and an estimated 4 man months' assistance from SCS. Martin E. Baudendistel, project leader.

February 3, 1947

FLOOD CONTROL SURVEY AND REPORT (REVISION)
FOUNTAIN CREEK WATERSHED

1. Field division: Flood control surveys
2. Work project: Flood control surveys
3. Line project: Detailed survey of approved watersheds for approving action program.
4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, cost, and benefits of measures needed to be applied for flood control and prevention of accelerated soil erosion on the watershed lands of the Fountain Creek, Colorado, drainage basin, and to prepare a report of these findings.
5. Review of past work: A watershed survey was conducted under the leadership of the SCS and a flood control report prepared and submitted in 1939. This report was not approved at the Department level but suspension of flood control survey activities during the war prevented the required revision.
6. Accomplishments during the past year: Resumption of flood control survey work in 1946 reactivated this survey. Agreement was reached in Washington by the FS and SCS that the report would be revised and brought up to date under supervision of the FS. All available pertinent file material, recorded data, maps and tracings were obtained from SCS and reviewed. The SCS at Albuquerque was contacted regarding over-all approach to the problem and preliminary plans worked out with that agency for the assignment of SCS personnel. A search for and study of new hydrologic data were started. The proposed survey program was discussed with the Rocky Mountain Experiment Station and Region 2.
7. Plans for next year: Complete new field work necessary for revision including assistance by SCS personnel. Complete report and obtain field clearance from interested agencies.
8. Date of completion: 1947
9. Assignment of personnel: Flood control personnel and an estimated 4 man months from SCS. Martin E. Baudendistel, project leader.

February 3, 1947

FLOOD CONTROL SURVEYS AND REPORT (REVISION - SCS)
QUEEN CREEK AND RIO PUERCO WATERSHED

1. Field division: Flood control surveys
2. Work project: Assistance to SCS on flood control surveys
3. Line project: Detailed survey of approved watershed by SCS for preparing action program. Forest Service participation.
4. Purpose: To provide technical assistance to SCS so as to determine the kind, cost, and benefits of measures needed to be applied for flood control, waterflow retardation and prevention of accelerated soil erosion on forested and associated range lands included in watersheds (Queen Creek, Arizona, Rio Puerco, New Mexico) which the SCS is responsible for surveying.
5. Review of past work: A watershed survey was conducted and a flood control report prepared and submitted in 1940. This report was not approved at the Washington level but suspension of flood control survey activities during the war prevented the required revision.
6. Accomplishments during the past year: Work outlines prepared by SCS were reviewed and approved. Several meetings were held with SCS personnel to discuss over-all procedure and proposed program. Personnel of Region 2 were detailed to flood control survey staff and assigned to Albuquerque office of SCS to handle FS phases of survey. This assignment amounted to approximately 3 man months. Meetings have been held with the Regional forester of Region 2 and his staff and with the Director of the Forest Service Southwestern Range and Experiment Station relative to Forest Service interests in the two surveys and the treatment measures to be recommended. The Forest Service portion of the Queen Creek report was completed and submitted to the SCS flood control survey staff. Field work on FS areas of the Rio Puerco survey was completed.
7. Plans for next year: Review report on Queen Creek watershed and obtain field clearance by Forest Service. Provide further assistance to SCS as requested.
8. Date of completion: Queen Creek survey - 1947
Rio Puerco survey - indefinite, probably will be included with the Rio Grande survey scheduled for completion in 1949.
9. Assignment: Lobenstein, Hardaway

PUBLICATIONS

1946

- Bailey, Reed W. Problems ahead in wildland research. Jour. Forestry, v. 44(11): 837-842. 1946.
- Craddock, George W. Salt Lake City Flood, 1945. Proc. Utah Acad. Sci., Arts, and Letters, v. 23: 51-61. 1946.
- Croft, A. R. A land-use management cycle. Jour. Forestry, v. 44(11): 819-822. 1946.
- Croft, A. R. Some factors that influence the accuracy of water supply forecasting in the Intermountain region. Trans. A.G.U., v. 27(III): 375-388. 1946.
- Ellison, Lincoln. How a subject-matter division in range can serve land management. Jour. Forestry, v. 44(11): 929-931. 1946.
- Ellison, Lincoln. The pocket gopher in relation to soil erosion on mountain range. Ecology, v. 27(2): 101-114. 1946.
- Holscher, C. E. Fire as a means of range betterment on brushland. Record Stockman 57(23): 7. 1946.
- Hutchings, Selar S. Drive the water to the sheep. National Wool Grower, v. 36(4): 10-11. 1946.
- Plummer, A. Perry. Mountain brome grass--good for seeding mountain ranges. National Wool Grower, v. 36(5): 14. 1946.
- Robertson, Joseph H. and C. Kenneth Pearse. Give your range seedlings a chance--reduce sagebrush and cheatgrass. American Cattle Producer, May 1946.
- Robertson, Joseph H. and A. Perry Plummer. Hints for use of the wheatland-type plows for brush eradication in connection with range re-seeding. Research Paper 13. July 1946.

STATION PERSONNEL - C. Y. 1946

ADMINISTRATION

Reed W. Bailey	Director
Irene O. Pope	Secretary
Walter E. Mann	Adm. Assistant
Marguerite A. Israelson	Clerk
Leona H. O'Donnell	Clerk
Evelyn C. Emerson	Clerk-Steno.
Lillian Eastman	Stenographer
Grant S. Williams	Clerk
Theta Barrett	Stenographer
Irene V. Hohlios	Clerk-Typist

RANGE INVESTIGATIONS

Grazing Management

Lincoln Ellison	Forest Ecologist
Clark E. Holscher	Forest Ecologist (range)
Selar S. Hutchings	Forest Ecologist (range)
Odell Julander	Forest Ecologist (range)
James P. Blaisdell	Forest Ecologist (range)
Justin G. Smith	Range Conservationist
Alvin T. Bleak	Range Conservationist
Carl J. Baird	Range Conservationist
Jack Major	Range Conservationist
Paul E. Hansen	Agricultural Aid
Rudolf Glauser	Agricultural Aid
Evan R. Johnson	Clerk-Steno.

Range Reseeding

George Stewart	Forest Ecologist
Alvin C. Hull, Jr.	Forest Ecologist (range)
A. Perry Plummer	Forest Ecologist (range)
Joseph H. Robertson	Forest Ecologist (range)
Richard M. Hurd	Forest Ecologist (range)
John M. Fenley	Forest Ecologist (range)
Neil C. Frischknecht	Range Conservationist
Marion H. Taylor	Agricultural Aid
Edmund L. Barraclough	Agricultural Aid

FOREST AND RANGE ECONOMICS

Arthur H. Roth, Jr.	Agricultural Economist
---------------------	------------------------

FOREST AND RANGE INFLUENCES

George W. Craddock
A. Russell Croft
Paul E. Packer
Howard W. Lull
Edward A. Johnson
Richard B. Marston
Alden Blain
Harry W. Pledger

Conservationist (forester)
Conservationist (forester)
Range Conservationist
Conservationist
Conservationist
Conservationist
Agricultural Aid
Foreman C&M

FLOOD CONTROL SURVEYS

Henry L. Lobenstein
Martin E. Baudendistel
John A. Adams
Elon H. Bomberger
J. Deloy Hansen
William E. Murray
Olaf C. Olson
Harold H. Price
J. Marvin Rosa
Kenneth W. Taylor
Albert R. Blanch
J. Smith Adair
Byron F. Thurmond

Forester
Conservationist
Engineer (civil)
Forester
Conservationist
Forester (range)
Soil Scientist
Conservationist
Hydrologist
Conservationist
Conservationist (flood)
Geologist
Cartographic Engineer